POWER

Established 1884—McGraw-Hill Publishing Company, Inc.

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VOLUME 74 NOVEMBER 24, 1931 NUMBER 21

Lessons of the Depression

These past five years have been replete with surprises. The depression itself has been the greatest. But from it old truths have been rediscovered and both people and business are returning to a form of basic reasoning that was quite outmoded in the spring of 1929.

There is no doubt that overcapitalization of prosperity has greatly handicapped economic recovery. One of the best evidences of this is in the suffering of big business with its doubled, trebled and quadrupled stock issues, well enough in prosperous times, but, in many cases, tragic today.

Contrast this with the smaller, and, yes, more conservative, businesses which have been satisfied with moderate expansion and not so large as to lose the unquestioned advantage of personal contact between management and men.

The vitality, success and continued profit earning of the well organized smaller businesses is one of the surprises of the depression and has set many larger businesses to thinking.

THE POWER DOLLAR

THE dollar, rather than the British thermal unit, is the basic unit of power engineering. Everything else is important only as it is an essential line in the dollar picture.

All engineers will admit this in the abstract. In practice, however, many pursue the elusive B.t.u. without full recognition of its varying dollar worth.

In this, heat-balance diagrams have caused some mischief. On such charts a B.t.u. in the coal pile is equal to a B.t.u. at the busbar. Thermally, this is true, but financially nothing could be further from the truth. Engineers who know better are often thrown off their balance, temporarily at least by excessive heat-unit thinking.

Since the dollar is the basic power service unit, *Power* here presents a series of cost-control charts which show the flow of power dollars just as heat-balance diagrams show B.tu. flow. Paralleling them are basic accounting forms which may be modified to fit, most conveniently, any particular installation.

The charts and forms are basic to any correctly set up system of power accounting, since they truly represent the interrelation of the various services, both generated and purchased.

It is decidedly interesting that a single chart (the master chart) can be drawn to cover the interrelation of parts in any conceivable kind of power plant, from a paper mill to a steamship.

The system here presented is based on the splitting up of the power plant into a series of "plants," each of which produces one or more power services. The operation of each of these "plants" involves a certain "total cost," which is spread over its power-service output.

Aside from help in the "costing" of manufactured articles, the only useful object of power accounting is to reduce the total power-service cost. The total power-service bill is the summation of the products of the quantity of each service and its unit cost. An intelligent search for economy will start with these individual products with intention to reduce them.

One factor, the quantity, is primarily in the hands of factory departments. Their consumption should be metered and charged, and (preferably) billed as an incentive to economy in use.

The other cost factor—unit cost—is entirely in the hands of the power engineer. He therefore needs an accounting system that will give him true unit costs of the power services and break them down far enough to reveal all important elements of these costs. To save money one must know where it goes.

The fundamental charts and forms here given fit perfectly the best existing systems of power accounting. They show the economic performance of each subplant, its relation to all the others and to "purchased-power" services.

Addressed primarily to the power chief—whether his title be "plant engineer," "power engineer," "chief engineer," "master mechanic" or "superintendent of power"—this number will be directly useful to men all along the line.

Operating engineers and shift engineers can learn much from the subcharts and forms, which include many expenditures for which they are immediately responsible.

On the other hand, top industrial executives, presidents, vice-presidents and treasurers, will find here a familiar language applied to a field they often but dimly understand. They think in terms of dollars and will see more clearly by the aid of those charts and forms why various improvements are good investments.

This number of *Power* is a companion to the "Hook-Up Number," dated Nov. 25, 1930. The latter dealt technically with fundamental sequences of major equipment. The present issue likewise deals with fundamental relations—this time financial.

POWER Stands for . . .

1. Making Power When It Should Be Made
2. Buying Power When It Should Be Bought
3. Cheaper Power Through Modern Equipment
4. Easier Financing of Equipment Purchases
5. Better Use of Byproduct Heat and Power
6. Operating Methods That Save Money
7. Less Waste in Transmission and Application
8. Prevention of Smoke, Within Reason

A Fundamental Approach to POWER COSTS

ONE WAY to develop a power accounting system is to start with none and add items as their need is proved. By assuming an imaginary case, and carrying through on this basis, the charts and forms here presented may be shown to follow logical lines.

Let us assume a great factory generating and using steam, electricity, refrigeration, hot water, compressed air and other power services. Assume also that the power executive is not at all interested in power-service accounting. He merely lumps coal, power plant labor, etc., in with all the other costs of producing the factory product. He neither knows nor cares how much steam, electricity or refrigeration costs, or how much is used.

To reduce manufacturing costs he urges everybody not to waste. Yet in spite of his best efforts the coal bill and other power costs remain unchanged. The power plant blames the factory for waste, while the factory blames the power plant for inefficient production.

To settle this argument and arrive at the cure, the executive installs meters showing the total output of each power service. In the absence of detailed data, he assigns such empirical values to these services that their total equals the total spent in producing them. That is, the total "value" of all services produced equals the total bill for coal, oil, ammonia, power-plant labor, and all other power service and maintenance materials and supplies, plus supervision, labor, depreciation, taxes and other overhead charges on equipment and buildings.

The unit costs assigned to these services indicate, let us assume, that the power plant is not doing so well as it might, although there is some argument as to whether the trouble lies in the engine room, the boiler room, refrigerating plant, or what not. Moreover, consumption is reduced very little, because each factory department claims that the others, rather than itself, are wastful. This new controversy is quickly settled by installing distribution meters and billing each department for its actual consumption.

Then the executive begins to consider another problem. He has felt that what happens inside of the power plant has been beyond him. He has, in effect, drawn a chalk line around this region of mystery, and has demanded an accounting only of what enters the sacred circle and of what leaves it. But more thought reveals to him two defects of this system, or lack of system. First, he has no assurance that the power costs are correctly distributed among the various services. Secondly, he has no way of seeing whether or not each element of the power plant is doing its economic best.

Clearly, it will be necessary to subdivide the large chalk circle into important elemental areas whose individual performance can be determined. He makes these divisions, calling each element a "plant," whether it is housed separately or not. A small hydro-electric plant at a distance is chalk-ringed as one plant. The boiler room is set apart as another plant. Turbines are ringed as a separate plant.

When this separation is completed new complications appear. One is that the same service is produced by several plants. In certain cases some portion of the same service is purchased as well. What can be done if the diesel plant produces some kilowatts at 1.6c., the steam plant some more at 1.8c., and still another portion is purchased at 2.0c.? On the reasonable assumption that one kilowatt is as good as another, regardless of individual costs, electricity from all sources is pooled together with its cost. The total cost, divided by total kilowatt-hours, gives the unit cost of electricity.

By means of such pools many other complex matters are easily handled. For example, some of the high-pressure steam is purchased and some is produced by the local boiler room. Some is delivered to plant processes, some to steam turbines and some to air compressors. All of the steam generated is pooled with that purchased and then distributed at a common unit price to manufacturing departments, turbines, etc.

Still another confusing problem arises. How about heating and ventilation? In addition to direct radiation, accounted for as steam delivered directly to the various departments, much air is distributed after being heated, cooled, washed or dehumidified, these operations requiring the use of refrigeration, water, steam and electricity. The resulting heating and ventilation service cannot conveniently be measured.

This difficulty is met by setting up an "air conditioning" plant, consuming the indicated services in measured amounts. Thus the total cost of this service can easily be figured each month. The percentage chargeable to each factory department is fixed once and for all by an estimated consumption of each department.

Finally he finds it necessary to set up a "miscellaneous" plant to absorb all the odds and ends not otherwise accounted for.

This imaginary executive has now what appears to be a complete system of power-cost records. From it he can determine the economic performance of each power-service group. He can get the actual cost each month of each power service and charge each manufacturing department for its actual consumption. Thus the very data that enable him to allocate power-service costs help him to reduce those costs.

One thing only is missing. That is some means of telling *why* the economic performance of a particular plant is poor. To trace such troubles to their roots the manager prepares a set of charts for the various plants. Just as the master chart breaks down the power plant into plants, so each of these charts breaks down a single plant into its major subdivisions. It is not found necessary to use all of these subcharts as part of the normal routine. One or two are used regularly.

The following article will present such a "master chart of the power services," designed to fit almost any conceivable kind of power plant. With it is presented a closely related "master accounting form" on which may be recorded all the interrelations shown on the master chart, and, in addition, fixed charges, operating supervision and labor, maintenance, miscellaneous supplies and fuel.

Master Chart of the Power Services

THE "Master Chart of the Power Services" (shown on page 733) is fundamental for any conceivable type of power plant.

The vertical central panel is divided into two parts. Above are the so-called "plants." Each of these "plants" is a portion of the entire power plant that generates one or more power services. Often the group is set off merely by an imaginary line from the rest of the power plant. Function, rather than location, must determine the division.

Service Pools

Each of these plants delivers one or more power services to the vertical arteries at the left. These, in turn, carry the services down to the "pools," which comprise the lower half of the central vertical panel. Before entering its pool, each power-service artery can absorb purchased-power and any other external expense.

These lines may convey power-service units or dollars, or both, and give an opportunity to take units generated or purchased at various costs and make them available at a single composite cost.

Thus kilowatt-hours may come from the hydro plant, from the diesel plant, or from the steam engine (or turbine) plant. Some may also be purchased. The pool absorbs the kilowatts from each source, and also the dollar-value of each batch. The total dollar-value divided by the total kilowatts gives the single unit cost of the pooled service. This is the unit cost at which it should be distributed for all further applications, either in the factory or in the power plant.

Many power services may be re-used, partly or entirely, in the power house. Such uses are completely provided for by the power-service arteries which rise vertically on the right, and which may deliver to any plant, and at the unit cost determined by pooling. All power service delivered by a given pool, and not running back up to plants, goes out along the horizontal line for distribution to factory or other external applications.

The horizontal lines entering or leaving the plants are inserted to cover practically any service that might be used or delivered by the various plants. No power plant would use them all. Occasionally it may be necessary to add a line or two or to utilize the "blank" plant or artery to cover some unusual condition. The power-service plan of any given plant will be represented by a portion only of this chart—generally a small portion.

It will pay to run through these plants briefly. First, the *Hydro* plant receives no outside service and delivers only electricity.

The *Diesel* plant also delivers electricity plus, occasionally, hot water or steam. For cooling it receives either city water or pumped water, that is, general-service water pumped by the pumping plant. If waste heat is recovered steam or hot water is delivered.

The *Engine or Turbine* plant receives high-pressure or intermediate-pressure steam, and frequently delivers intermediate-pressure or low-pressure steam as well as electricity. If operated condensing it returns condensate to the boiler room.

In connection with the various *Boiler* plants (4, 5 and 6) the system of steam pressure must be explained. To provide for all possible conditions, three pressure levels are provided: High, intermediate, and low. These pressures are purely relative, and may represent any three levels. In one power plant the three pressures might be 1,400, 200 and 50 lb.; in another, 300, 100 and 10 pounds. Three levels (not including condenser level) will take care of most industrial plants.

Each of these boiler plants receives condensate, also city water or pumped water (outside pumped) for make-up, and normally requires kilowatt-hours as well for auxiliary operation. Feed treatment, feed heaters, feed pumps, and coal preparation are all included in the boiler plant.

The *Water-Pumping* plant may receive city water, or take its water from a local source. It may use compressed air for an air lift. The pumps for local source or city water may be driven by electricity, or by high-pressure or intermediate-pressure steam. The output, in addition to pumped water, may include intermediate-pressure or low-pressure steam.

It is not implied that pumped water is in all cases to be listed as a power-service distinct from city water. This may be the case only where the pumping involves a substantial expenditure. Where the pumping is a minor matter, so that separate accounting would not be justified, the miscellaneous plant provides a simple means of absorbing this cost. The same applies to any other power service item of minor importance. It should be noted, moreover, that the water pumping plant does not include feed pumps, circulating pumps or other pumps devoted solely to the use of individual plants. It must, of course, include wells.

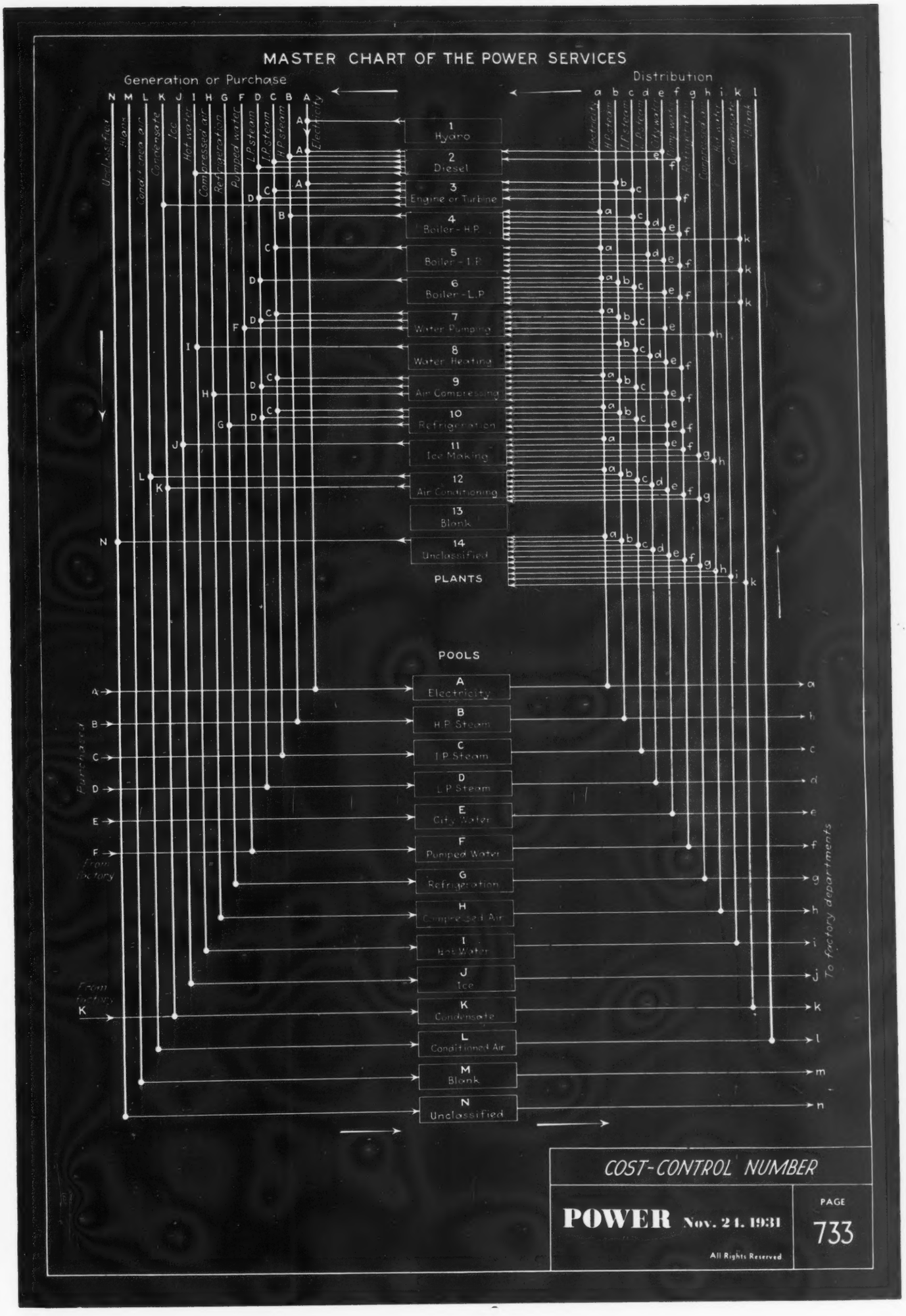
The *Water-Heating* plant is often one of considerable importance, particularly in hotels, textile plants, laundries, etc. Considering the water-heating equipment as a plant makes it possible to figure the actual cost of hot water, even where the water is separately pumped and where steam from various sources, and at various pressures, is used.

Air Compressing likewise requires either electricity or high-pressure or intermediate-pressure steam. It also requires cooling water (city or pumped).

The output of the compressor plant is compressed air, and also possibly intermediate-pressure or low-pressure steam where the compressors are steam driven.

To cover the many cases where no ice is produced, or where part of the refrigeration generated is used for purposes other than ice-making, both *Ice* plant and *Refrigeration* plant are included.

Operation of the refrigeration plant requires electricity or steam (intermediate pressure or high pressure). It also requires either city water or pumped water for cooling. Its output is refrigeration plus, sometimes, intermediate- or low-pressure steam. The



COST-CONTROL NUMBER

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ice plant receives electricity, city water, pumped water, and refrigeration. When ice is the sole product of a refrigeration plant it can, if desired, be shown as the direct output of that plant.

Before discussing the remaining plants it will be well to consider further the inter-relation of the various plants and pools. In every application of power accounting there are some cost items so small, or so difficult of access, that a detailed true accounting would not be worth its cost. In such cases it is proper to use some catch-all device for lumping such items.

Sewage ejection service in a building is an example. It would generally be unnecessary to meter the pumped sewage by departments. The same generally applies to sump pumps. Or the power plant may contain a small air compressor for incidental use. Its steam or electric consumption may be so small that a separate accounting for this compressed air would be ridiculous.

Again, in many plants, general water pumping is a minor item and does not warrant separate accounting. In some plants city water may be used in large quantities in the power plant, whereas very small quantities are used for drinking in the factory. The latter consumption may not warrant metering by departments.

In the aggregate, however, these minor items may be appreciable. They must in any case find their way into the total, and be distributed in some manner over consuming departments.

The master chart provides a simple and practicable means of handling such items. Near the bottom of the plants is a block entitled "Unclassified." Into this "plant" are grouped all the odds and ends not worth separate classification, such as vacuum cleaners, small compressors, small pumps, etc. This catch-all may also be used to absorb small losses in transmission, or discrepancies in meter readings, so as to create an exact bookkeeping balance between the units generated and those distributed.

For each accounting period the cost of all services dumped into the unclassified plant may be totalled. For distribution of this cost it may be assumed that 100 unclassified units are generated, and that these are always to be distributed according to a definite schedule, say, eight units to Department I, thirteen units to Department II, etc. This distribution may be based on floor area, on number of workers, or any other reasonable basis. Each unit carries 1 per cent of the total unclassified expense.

A similar device is used to take care of that portion of the part of the heating and ventilating service that is not readily distributed through departmental meters.

High-pressure or low-pressure steam supplied directly to departments should generally be metered and charged directly, but there are frequently other items of heating and ventilation not easily metered for distribution. Suppose, for example, there is an air-conditioning and ventilating plant which consumes electricity, water and steam and delivers conditioned air to several buildings.

To handle such items an air-conditioning plant is set up, to which all of these special items can be charged. The output can be fixed at 100 heating and ventilating units, each carrying 1 per cent of the total cost.

These units may be distributed according to a fixed schedule based on a fair estimate of the relative consumption of conditioned air by various factory departments.

As already pointed out, the master chart shows power services only. These and the other cost elements are included on the master accounting form described in the next article.

It is important to note that all power services' cost, of whatever nature, must find a place (or places) among the various plants. For example, a transmission line from the hydro plant to the factory must be included as part of the hydro plant and power must be measured at the delivery end of the line.

Generation or Purchase

N	M	L	K	J	I	H	G	F	E	D	C	B	A	
Unclassified Units	Blank	Conditioned Air	Condensate 1000 lb.	Ice Tons	Hot Water 1000 lb.	Compressed Air 1000 cu.ft.	Refrigeration Tons	Pumped Water 1000 lb.	City Water 1,000 lb.	Low-Pressure Steam 1,000 lb.	Intermed.-Press. Steam 1000 lb.	High-Pressure Steam 1000 lb.	Electricity 100 kw.	Plants
Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	Q $ ¢	
													A1	1 Hydro
					I2					D2	C2	B2	A2	2 Diesel
			K3							D3	C3		A3	3 Engine or Turbine
												B4		4 Boiler—H.P.
											C5			5 Boiler—I.P.
										D6				6 Boiler—L.P.
								F7		D7	C7			7 Water Pumping
					I8									8 Water Heating
						H9				D9	C9			9 Air Compressing
				J10			G10			D10	C10			10 Refrigeration
				J11										11 Ice Making
		L12												12 Air Conditioning
	M13													13 Blank
N14														14 Unclassified
									E15	D15	C15	B15	A15	15 Purchased
N16	M16	L16	K16	J16	I16	H16	G16	F16	E16	D16	C16	B16	A16	16 Total
N17	M17	L17	K17	J17	I17	H17	G17	F17	E17	D17	C17	B17	A17	17 Unit Costs

MASTER ACCOUNTING FORM

Accounting Based on the Master Chart

EACH PLANT on the master chart (page 733) represents, for a given period, a given cost. This cost may be divided up in a number of ways, but for the purpose of this summary we shall divide it simply into the following parts: Power services supplied, fuel, fixed charges, operating supervision and labor, maintenance, and miscellaneous.

A "Master Accounting Form," on this and the facing page, corresponds closely to the master chart and, like it, shows on a single sheet the interrelation of all the plants and consuming departments. It goes beyond the master chart, however, in showing all cost elements listed above, not merely the power services.

System of Lettering

To simplify reference to spaces on this form, they are lettered and numbered according to a system which will be obvious by reference to letters that head the power-service columns, and the numbers attached to the plants. Roman numerals are used to designate factory departments. Identical reference characters are used on the master chart.

Practically all possible entries are covered by the rectangles marked with the letter of the column and the number of the line. Any given plant would, in general, use but a small fraction of these entries. For application to any particular power plant the form can be made smaller by omitting all lines and columns that do not apply.

Form Follows Chart

On the form, as on the chart, plants (1-14) in the central vertical column deliver services to the columns at the left, corresponding to the vertical arteries of power services of the chart. The power services generated (including those purchased) accumulate in line 16 on the left. Both dollars and power-service units accumulate there. Line 16, therefore, corresponds to the pools of the chart. The unit costs of line 17 on the left are computed from the data on line 16.

Services as listed in the columns at the right are delivered to the various plants at the unit rates listed on line 17 (right), which are necessarily the same as those in the correspondingly lettered columns of line 17 on the left.

Columns *u, v, w, x, y* on the right give costs to be added to those of the entering power services to get the total costs of all services delivered by the given plant.

Services produced and not redistributed to plants are necessarily distributed to manufacturing departments.

| | | | | | | | | Distribution to Plants | | | | | | | |

Spaces for this distribution are provided on the lower right.

The sums of departmental totals (line VI) and the plant application totals for each service (line 16, right) are given in line VII and must equal the generated total (line 16, left). By using line 14 (miscellaneous plant) to absorb all minor wastes and services, as well as discrepancies in meter readings, an accounting balance is possible.

First Fill In Known Data

It is evident that a form of this sort cannot always be filled in line by line, that is, by working from top to bottom and from left to right. The reason, already mentioned, is that the cost of one power service may depend upon that of another. The proper procedure is to fill in all known data first. These include the quantity of each power service used and produced by each plant. They include also power services purchased and those delivered to each pool and to the factory. In addition to power services, the data to be recorded at the start include (for each plant) fixed charges, operating supervision and labor, maintenance, miscellaneous, and fuel.

When these entries have been made the next step is to compute the cost of delivered services, starting as "early" as possible in the power-service series. The boiler plant, for example, naturally comes before the engine plant, and the latter before, say an electrically driven compressor plant. Complete costs can be filled out at once for any plant which does not use other power services. If a barrier is reached it is necessary to start again at another point.

So described, this procedure sounds rather vague, but in any practical application the sequence is easily discovered. This will be clearer later when a specific plant is used to illustrate the use of this chart and form.

Solving a Dilemma

In practice such a barrier is found chiefly in cases where electrically driven auxiliaries are used in the boiler room which supplies steam to factory departments and to the turbine room, which, in turn, generates electricity, part of which is used in the boiler room. Clearly, to find the cost of electricity, one must know the cost of steam, which, in turn, depends, in part, upon the cost of electricity.

What can be done in a case of this sort? One simple and practical procedure is to use in the boiler room not the actual cost of electricity but a "standard" cost based on previous experience. Since electricity is but a small part of the cost of steam, the difference between the true and the estimated costs of auxiliary electricity will have no important effect on the cost of steam.

To get an exact balance in the electrical columns such an error in unit cost may be absorbed in the "Unclassified" plant. That is, if the unit cost of the electricity supplied to the boiler plant proves later to be a little above the true value, the unit cost in the unclassified plant can be lowered enough to balance.

For those who prefer a theoretically correct procedure there is a strictly scientific method of ascertaining steam and electrical costs when they are interdependent.

To do this, proceed as follows: First find what fraction of all the electricity produced by the turbine room returns to it in the shape of boiler-room auxiliary power. Call this recirculated fraction R. Then figure the cost of all electricity delivered by the turbine room, including all elements except the recirculated electricity. Call this total e. Then the actual cost of recirculated electricity is $e(R + R^2 + R^3$, etc.). The series converges rapidly and rarely need be carried beyond three terms. Often two will be sufficient.

Example

Suppose, for example, that the turbine plant delivers 70 per cent of all electricity supplied to the electricity pool and that 4 per cent of pool electricity goes to the boiler room. Then $R = 0.7 \times 0.04 = 0.028$.

Assume, also, that the turbine room delivers 850,000 kw.-hr. at a total cost (except recirculated electricity) of $9,500. Then the recirculated electricity is

$$9{,}500\ (0.028 + 0.000784 + \ldots\ldots)$$
$$= 9{,}500\ (0.028784)$$
$$= \$273.45.$$

Then the total value of electricity produced is $9,773.45. Recomputing auxiliary power as a check, we get $\$9{,}773 \times 0.028 = \$273.60$. The error is only 15 cents.

A glance at the master chart and the master form will suggest another question. What should be done when a plant produces more than one power service? For example, in the engine plant, how shall the total plant cost be apportioned between the exhaust steam and the electricity produced?

To obtain the answer divide the low-pressure steam leaving the low-pressure steam pool into two portions: that used (in plants or factory departments) and that wasted to atmosphere.

Charge consuming plants and departments for the used portion only at a unit cost equal to the actual use-value of this steam. This use-value may be taken as the estimated cost of generating this steam in a low-pressure boiler plant, or it may be taken as the cost of an equivalent heat value in high pressure steam. Multiplying this unit cost by the number of units actually used gives the useful dollars delivered by the pool. Take the same number of dollars as entering the pool but apply it to the *total* quantity of low-pressure steam. This gives this steam a lower unit cost based on its usability. This unit cost is then carried back to each plant delivering low-pressure steam.

The same procedure is applied to the intermediate-pressure steam pool.

The condensate returned by steam-operated units and by the factory is always usable and more desirable than city water. It may therefore be given an arbitrary unit cost somewhat higher than that of city water or pumped water.

Diesel waste heat in the form of hot water may be valued at the cost of producing similar water by steam water heaters.

It should again be pointed out that all costs on the master form can be determined without studying the inside arrangements of any plant. It is only necessary to know what enters and what leaves.

The individual plant charts discussed in the following article are not required for this purpose.

MASTER CHART EXAMPLES

THE MASTER CHART and accounting form presented in the previous article will at first glance appear to be exceedingly complicated. The reason for this is that it has been prepared so that it will apply to almost any conceivable power station and combines all possible power services. Very few industrials have power stations that deliver all of the services provided for by the master chart. Thus for the average plant the master chart may be greatly simplified. To show how simple this chart becomes when applied to a given station, and to indicate its universal use, the following examples are presented, showing the application of the chart to five widely differing plants.

INDUSTRIAL POWER PLANT

The chart, page 738, applies to an industrial power station that furnishes electricity, intermediate- and low-pressure steam for factory use. High-pressure steam is delivered from the boiler house through the high-pressure steam pool *B* to the engine or turbine plant (3). This plant contains a bleeder and a back-pressure turbine. The output from the engine or turbine plant is condensate and intermediate-pressure steam from the bleeder turbine, low-pressure steam from the back-pressure turbine, and electricity.

Electricity is pooled with purchased power at *A* and delivered to the factory and to the vertical service line to be distributed to various uses in the power house. Although no purchased electricity may be used a cost may be incurred because of a stand-by service arrangement with the central station.

Intermediate- and low-pressure steam are used in the boiler plant for feed-water heating, and the remainder is delivered to the factory. Condensate from the factory and from the bleeder turbine is pooled in *K* and delivered back to the boiler room. A water-pumping plant (7) is shown.

ICE PLANT

A diesel-electric ice plant is represented in the second chart, page 739. Here the diesel engine plant (2) provides electric energy through pool *A* to the refrigerating plant (10), the ice-making plant (11) driving the ammonia compressors and various associated auxiliaries, and the water pumping plant (7). The refrigerating plant (10) delivers refrigeration through pool *G* to the ice-making plant (11), whose output is ice, which is delivered through the pool *J* to factory. A pumping plant containing electrically driven pumps supplies water for auxiliary uses in the ice plant. Likewise, an air compressing plant is shown, which provides compressed air for can agitation service in the ice plant. The cost of this service is extremely small, and may, if desired, be included in the ice-making plant instead of setting up a separate plant for it.

WATER SUPPLY PLANT

Chart 3, page 740, represents a city-water-pumping plant. As shown by the chart, this plant contains an intermediate-pressure boiler plant (5), engine or turbine plant (3) and water-pumping plant (7). The engine room contains a condensing engine-generator set which delivers electricity to the water-pumping plant for operating several motor-driven pumps. The water pumping plant also contains a turbine-driven pump, delivering its low-pressure exhaust steam to the boiler plant for feed heating. Condensate from the engine or turbine room is delivered through pool *K* back to the boiler plant, and there heated by exhaust steam from the pumping engine. Pumped water from 7 is delivered through pool *F* to the factory or city main.

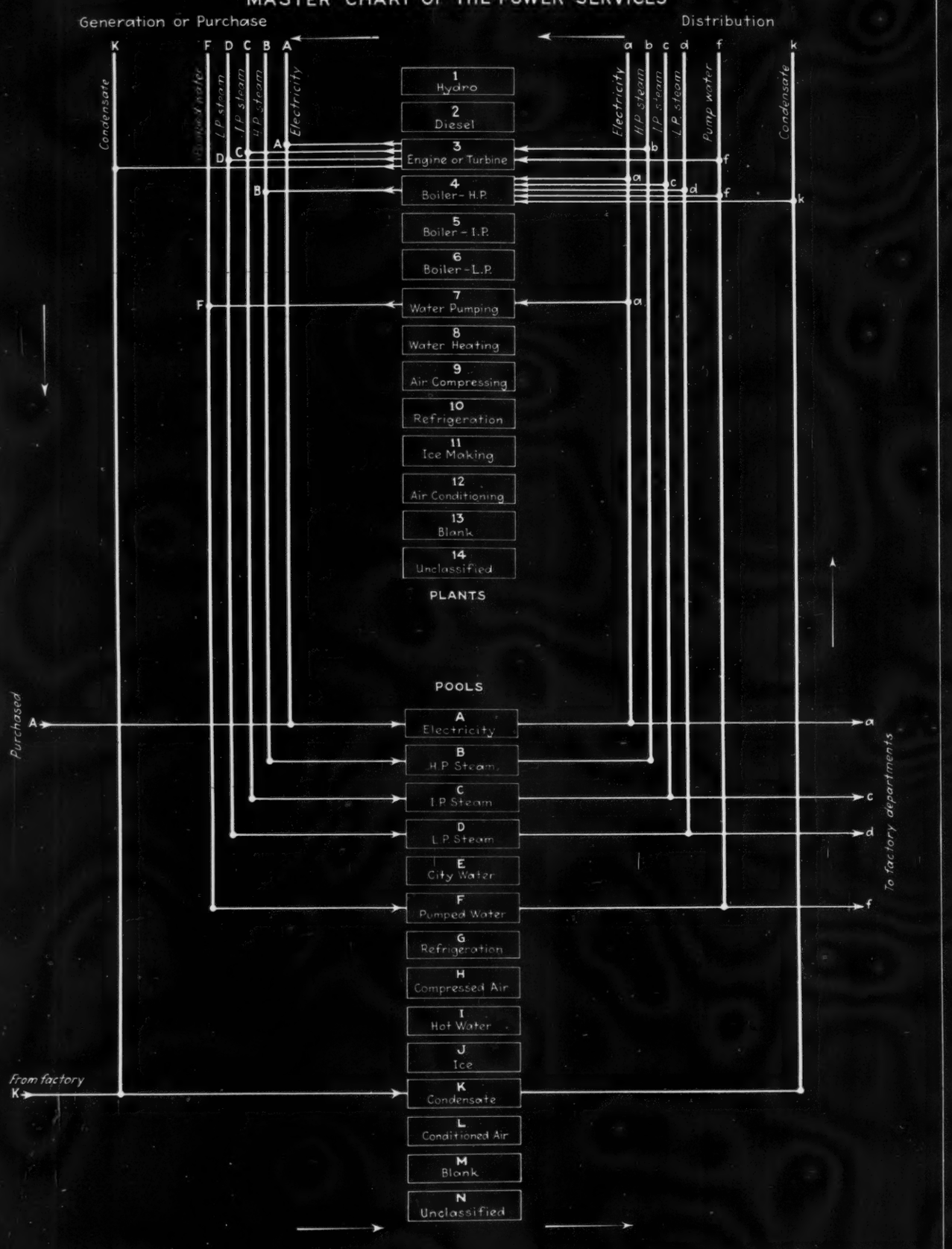
HOTEL PLANT

The fourth chart, page 741, is somewhat more complicated, and shows how the plant serving a hotel may be divided into subplants for analysis. This hotel plant generates steam in a low-pressure boiler for heating during the winter season, and for kitchen and heating hot water all year round. Electric energy is purchased, as is also city water. A refrigerating plant is installed for air conditioning, and for supplying refrigeration for other hotel purposes in the kitchen. A pumped-water plant takes care of the pumping of water for hot and cold water uses throughout the hotel, and in the kitchen and laundry.

UTILITY PLANT

The fifth example, page 742, indicates a small utility plant comprising a high-pressure boiler plant, a turbine plant containing units that deliver bled steam at two pressures for feed heating, and a water-pumping plant that supplies water for general service use. In this plant electricity is the only output, and must bear all of the cost of plant operation.

MASTER CHART OF THE POWER SERVICES



INDUSTRIAL POWER PLANT

POWER Nov. 24, 1931
Cost-Control Number

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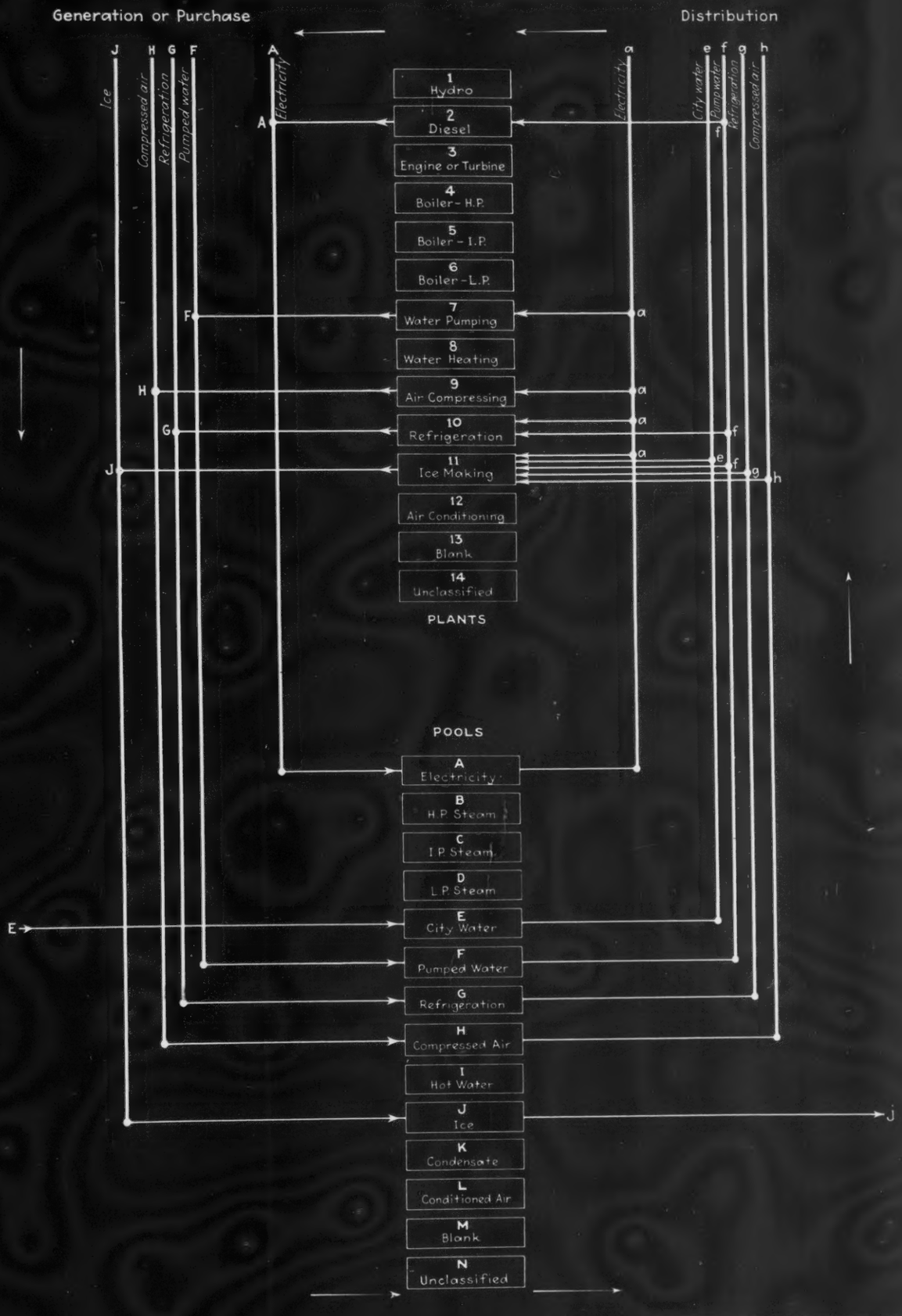
MASTER CHART OF THE POWER SERVICES



ICE PLANT

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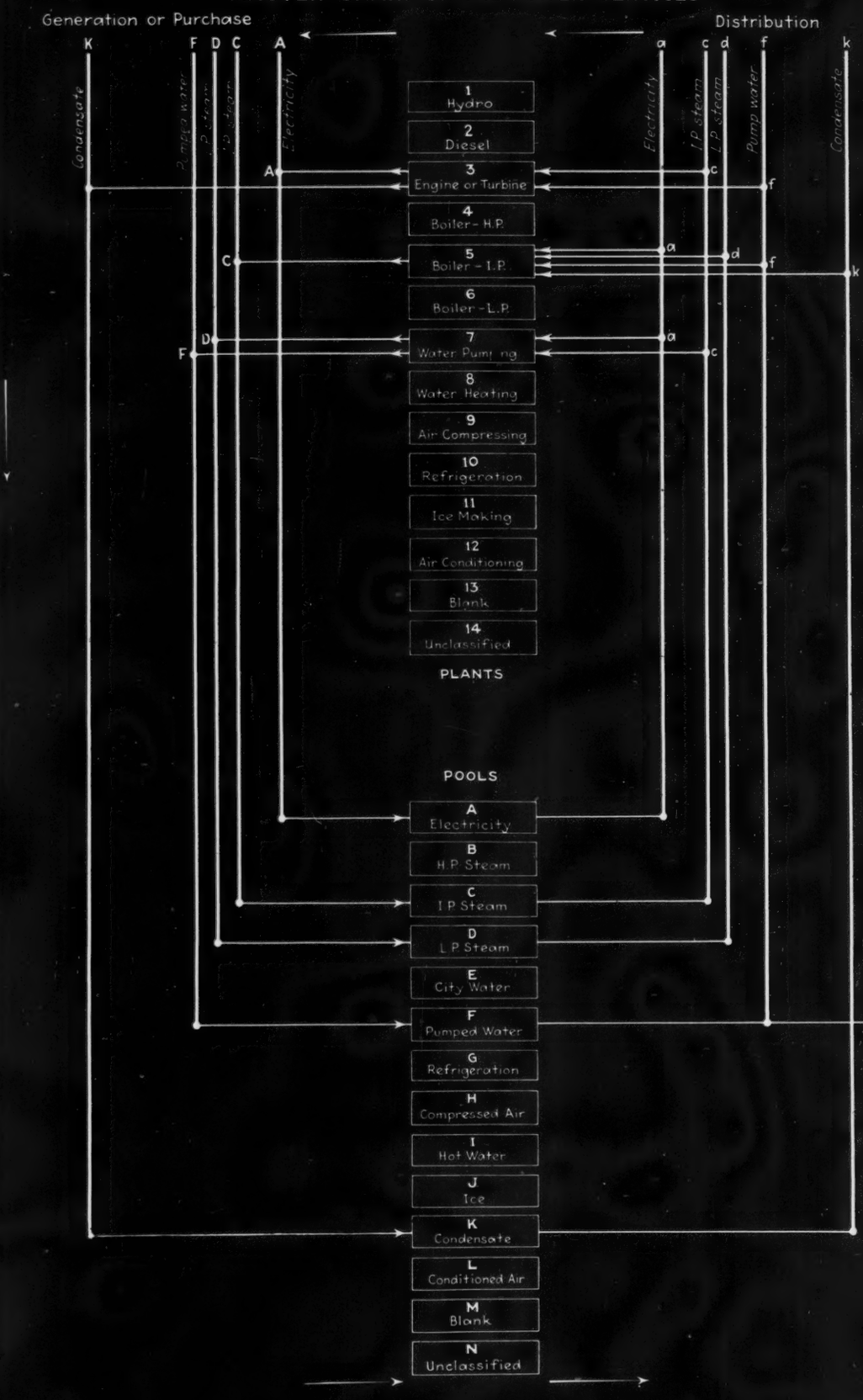
MASTER CHART OF THE POWER SERVICES



WATER SUPPLY PLANT

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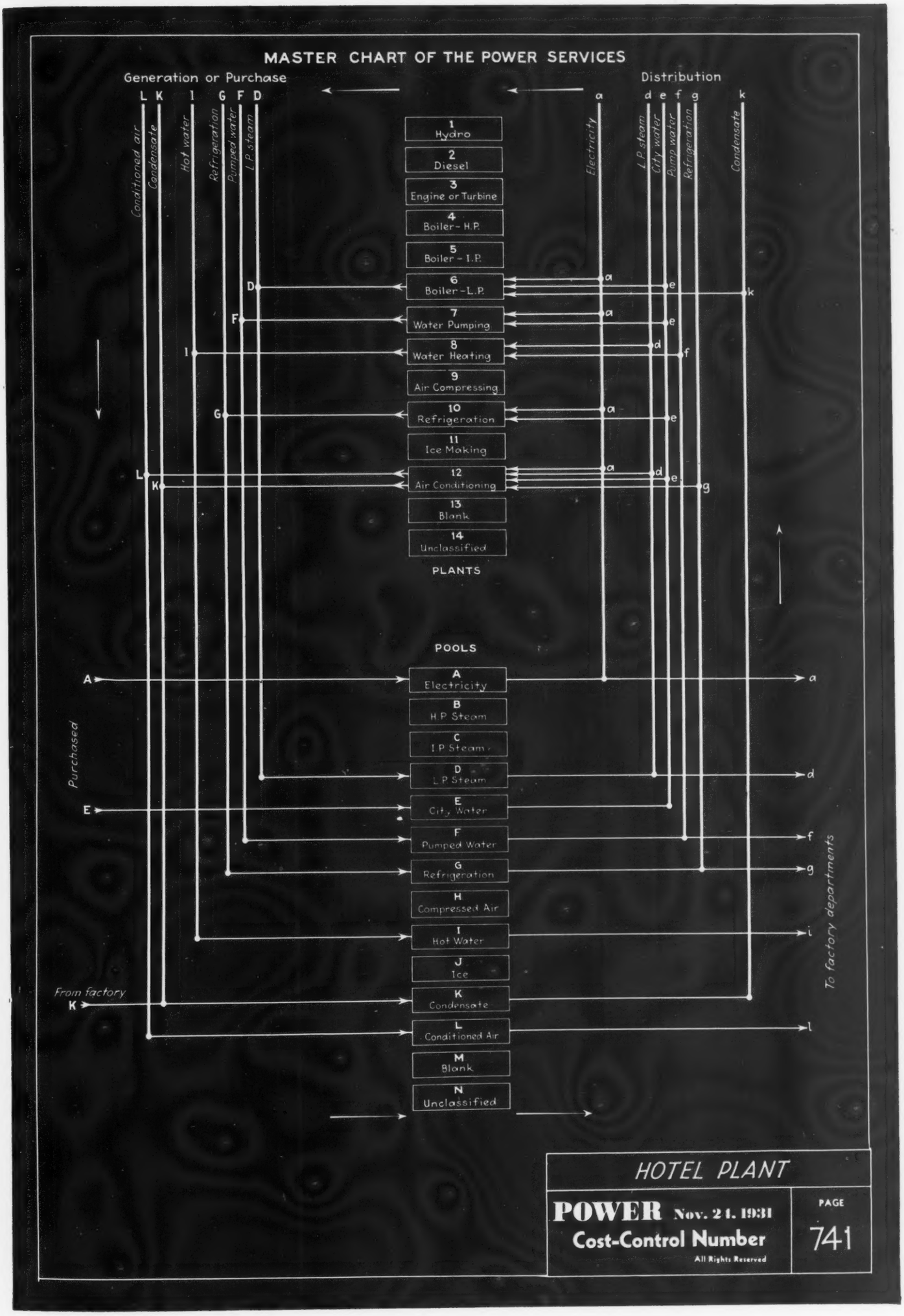

HOTEL PLANT

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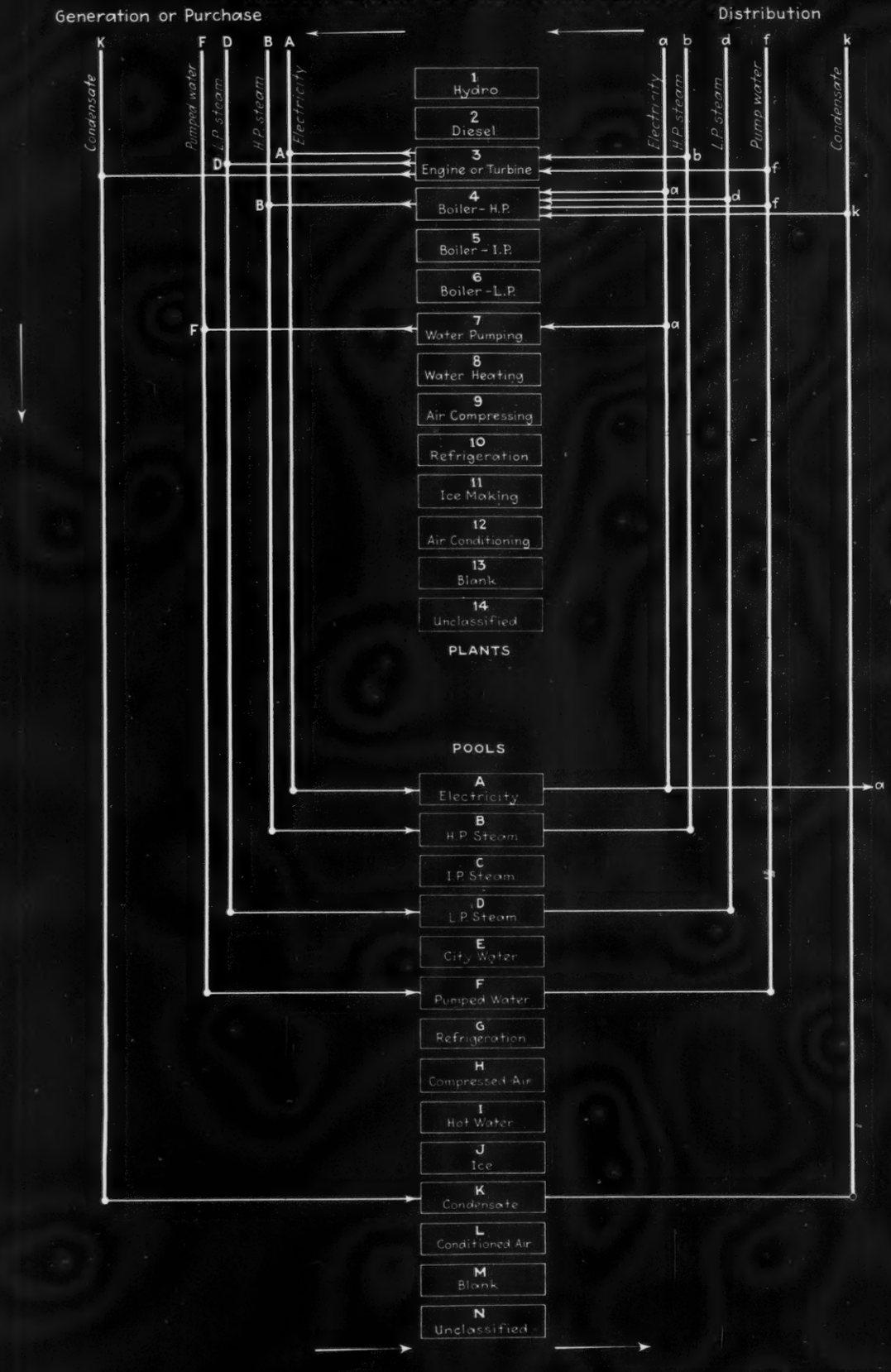
MASTER CHART OF THE POWER SERVICES



UTILITY POWER PLANT

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Plant Accounting

AS ALREADY pointed out, the master chart and master accounting form give the cost of each power service as it leaves each plant and as it enters and leaves its pool. In many cases no further analysis is necessary.

It frequently happens, however, that one or more of the plants is sufficiently complex and sufficiently important to warrant internal analysis. The master chart, for example, may indicate that the boiler room is not doing as well as it might. To find where the trouble lies it is necessary to analyze the boiler plant just as the master chart and form are used to analyze the whole power plant. The articles that follow contain such analyses, with individual charts and accounting summary forms for all of the plants shown on the master chart, with the exception of ice making.

To simplify the use of these charts, the description in each case is in concise form. It is therefore necessary to give here some general comments that apply in all cases. These general comments and forms will be better understood by reference to the chart and form (filled out) in one of the articles which follows.

Unlike the master chart, which shows lines for power services only, the lines in the subcharts cover all costs. At the right of each diagram is a group of ascending lines and at the left a group of descending lines. Those that enter below, on the right, are all power services, with the exception of the first four, labeled as follows: *u*, Fixed Charges; *v*, Operating Superintendence and Labor; *w*. Maintenance; and *x*, Miscellaneous. The power services shown carry the same letter designation as in the master chart.

Running down and out at the left are the power services delivered back to the system by the plant. In a few cases there is a cross line from this delivery over to the corresponding service rising on the right, from which service is redelivered to divisions of the plant.

In making plant subdivisions the accounting purpose was kept in mind—the desirability of bringing things of a kind together, so that sources of loss may be more easily uncovered.

A fuel line *y* leads directly to the subdivision using it.

Each subdivision is identified by a two-digit number in which the first digit is the number of the given plant on the master chart.

The accounting form shown on the left-hand page of each article corresponds, item for item, with its facing chart, and bears the same relation to that chart as the master form does to the master chart.

Vertically, each form is divided into two parts, the upper representing costs coming in and the lower representing the values going out. As on the chart, the values coming in consist, first, of items *u, v, w, x, y,* already mentioned, then the power services shown by the other vertical lines starting up at the right of the chart, and finally by the other values entering one or more of the subdivisions but not entering the plant as a whole.

The lower part of the form shows the values going out, including power services, and also values that leave one subdivision for another but do not leave the plant.

To reduce the spaces required for entry, units of suitable size are used. These are indicated in the first column. For example, the electrical unit is 100 kw.-hr. That for steam and water in all forms is 1,000 lb. That for compressed air is 1,000 cu.ft. of free air. That for refrigeration is the "refrigeration ton," the term being used to represent the *quantity* of heat removed, and not the *rate* of heat removal. This will be explained more fully under refrigeration. The unit of ice-making is a ton of ice. No units are used for the "Air Conditioning" and "Unclassified" plants.

Following the column of units are columns for the various subdivisions. Finally, there is a column for the "Total" of these, another for the "Net" (to be explained), and one for the "Unit Cost" of the units listed at the left.

The columns for the subdivisions, the "Total" and the "Net" are divided into spaces for the quantity marked *Q*, and for the corresponding cost, marked $ and ¢. The quantity cannot, of course, be entered in the case of the first four columns (*u, v, w, x*), and may be omitted elsewhere wherever desired.

Considering, for the time being, only the part of the chart at the left of the "Net" column, the dollar columns are added vertically and then horizontally. Vertical addition gives the dollar input and output of each subdivision. These two must be equal. Quantities may be added horizontally, but not vertically.

Horizontal addition gives the summation of each service coming and going out of each subdivision. This, by itself, has no particular meaning, since a certain value may pass through several divisions in series, and thus get counted several times. This total column is of use only as it enables one to get the "Net" in the column that follows. The "Net" column is filled in by entering the difference between the ingoing and outgoing "Total" for any service, on the incoming or outgoing space, whichever is greater. This column, then, shows the values entering or leaving the plant as a whole. These should correspond with those on the master chart and form. This operation will become clear by a study of the accounting form entries in the articles immediately following this.

It should be pointed out again that it is not necessary to keep up subcharts and forms for every plant. They need only to be used where considerable sums of money are involved, and where breakdown of the plant will make possible substantial savings by revealing sources of loss.

Although the charts and forms have been made as flexible as possible, it is not possible to show every conceivable combination of equipment. Those shown, however, are sufficient to indicate how any particular set-up may be analyzed.

HYDRO PLANT

ON THE master chart the hydro plant is presented as a part of an industrial power plant. Many such combinations exist, particularly in New England and Canada. Some of these hydro plants are of large capacity, justifying such a breakdown as that here shown. Others are of minor importance, so that the over-all relations and costs shown on the master chart and form give all needed information. Where the plant is at a distance from the point of application, account must be taken of transmission costs, including transmission losses as well as all fixed and operating costs of the transmission line. In the breakdown here shown these are included in Subdivision 16. If only the master form is used for over-all costs, all transmission costs should be included and energy measured at the delivery end.

SUBDIVISION 11

Water Rights—Real Estate—Rights-of-Way — Storage — Regulation: Includes dams and everything else necessary to deliver water to the conduits (Subdivision 12). Flow line *1c* will be explained under Building 15.

SUBDIVISION 12

Water Conduits—Surge Tanks—Penstocks: Includes everything necessary to convey water from 11 to 14, and from 14 to the tailwater.

SUBDIVISION 13

Miscellaneous Auxiliaries: Includes power house auxiliaries not included with the main units (14) such as oil and water pumps, and air compressor.

SUBDIVISION 14

Main Units—Associated Auxiliaries: With the main turbine generators are here associated those auxiliaries that serve them directly. Thus the electricity delivered to 15 is net after subtracting that used by these auxiliaries.

SUBDIVISION 15

Building: This covers building costs and all other power plant costs not included in 14.

Line *1c* requires special explanation. It sometimes happens that the design of a hydro-electric power house is influenced by the presence of other plants on the stream, because of variations in their water requirements.

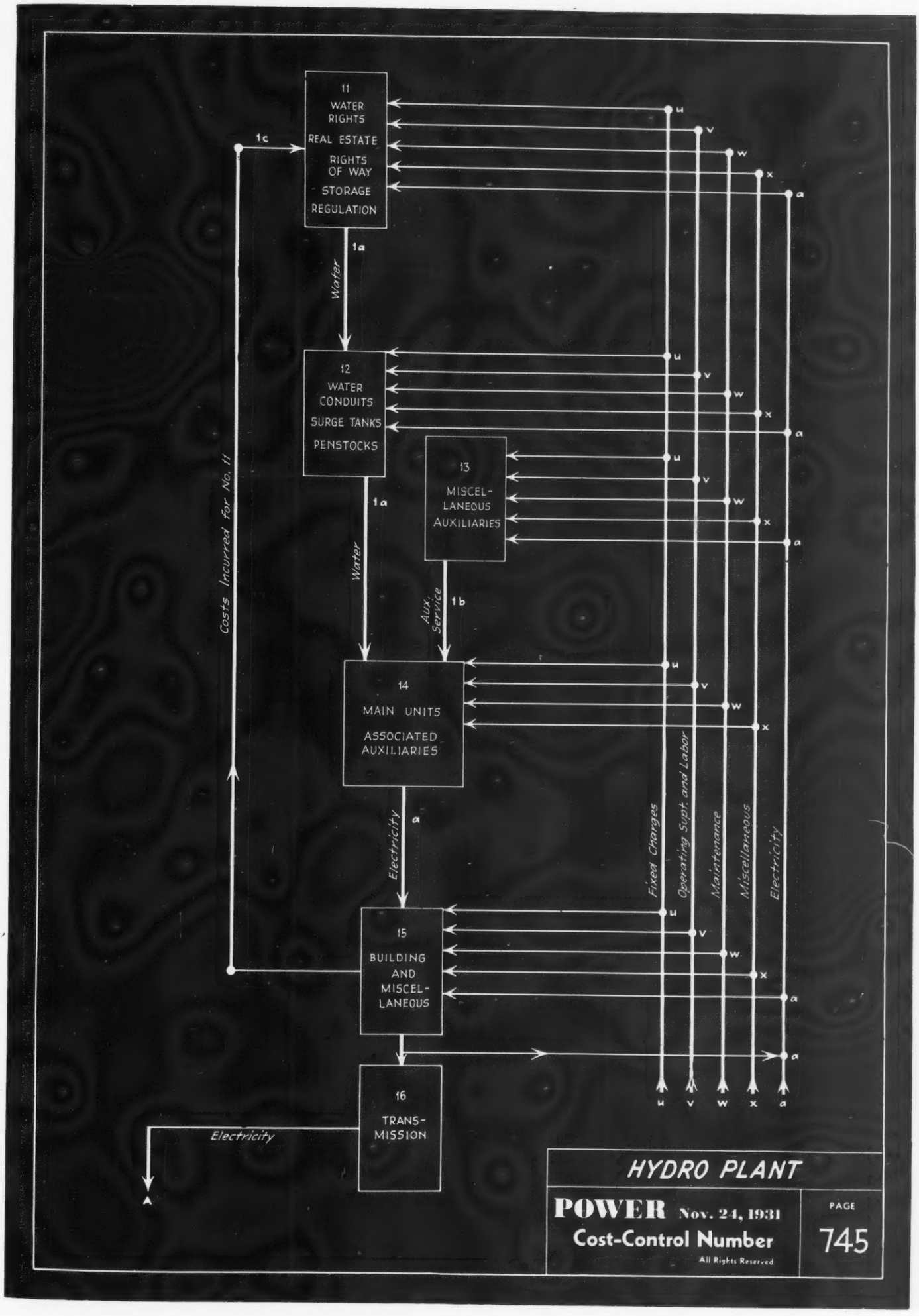
If desired this may be recognized on the accounting system by using flow line *1c*, which transfers to 11 that portion of the total cost entering 15 that is created exclusively by the necessity of creating certain desired conditions for other plants on the same river. For example, this plant might install more turbines than normal in order to accommodate a maximum water flow determined by other plants. It might therefore operate at a subnormal plant factor with a resulting higher cost per kilowatt, due particularly to excessive fixed charges.

SUBDIVISION 16

Step-Up Transformers—Transmission: Includes all costs necessary to transfer electricity from wall of hydro plant to wall of factory. Electrical input and output of 16 differ by the amount of transmission loss.

	GOING IN	Unit	11 Water Rights, Etc.			12 Water Conduits			13 Miscellaneous Auxiliaries			14 Main Unit			15 Building and Miscellaneous			16 Transmission			Total			Net			Unit Cost	
			Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	$	¢
u	Fixed Charges			400			50			10			200			200			50			910			910			
v	Operating Sup. and Labor						15			10			240			60			30			355			355			
w	Maintenance						5			3			15			7			20			50			50			
x	Miscellaneous												5									5			5			
a	Electricity	100kw-hr.							8	24					4,284	983		4,284	1,250		8,578	2,257						
1a	Water						400						470									870						
1b	Auxiliary Service												47									47						
1c	Costs for No. 11																											
	Total In			400			470			47			977			1,250			1,350			4,494			1,320			
	GOING OUT																											
A	Electricity	100kw-hr.										4,284	977		4,284	1,250		4,284	1,350		12,852	3,577		4,274	1,320			31
1a	Water			400			470															870						
1b	Auxiliary Service									47												47						
1c	Costs for No. 11																											
	Total Out			400			470			47			977			1,250			1,350			4,494			1,320			

The round numbers inserted in the above table are designed solely to illustrate its application. They should not be taken as representative of either good or typical practice.



HYDRO PLANT

POWER Nov. 24, 1931
Cost-Control Number

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DIESEL PLANT

IN SETTING UP a master chart for a diesel plant, the procedure is identical with that necessary in case of a steam plant, but much shorter by reason of the decrease in the number of services and subdivisions. As shown, the diesel plant takes in fuel, cooling water, labor, maintenance, fixed charges and miscellaneous and delivers electricity and hot water or steam, the latter resulting from the warm jacket water further heated by the exhaust. In other plants no advantage may be taken of this jacket water. Should the exhaust heat be used to warm kiln air this will merely alter the output service from Subdivision 23. The lubrication oil cost is included under the miscellaneous item entering 23.

SUBDIVSION 21

Fuel: Entering Subdivision 21 is the cost of the fuel delivered in tank cars or otherwise, plus the fixed charges on the fuel-handling equipment, the electricity needed in handling the fuel, operating labor and maintenance. If it is necessary to heat the fuel, hot water service should be charged to the fuel system.

SUBDIVISION 22

Cooling Water: Cost of cooling water embraces the elements of operating labor, pumping, electricity, maintenance, make-up water, and fixed charges on equipment, such as piping, cooling tower or spray pond and pumps. Jacket water put through an exhaust heater and then pumped to the factory for heating purposes may be returned to the cooling system again. When this occurs it is easier to charge the cooling system with the water returned from the factory and credit it with the water sent to the engine jackets.

SUBDIVISION 23

Lubrication System: Into the lubrication system goes all the various elements of cost, including that of filtration. The cost of the make-up oil is, in the chart, embraced in the miscellaneous item. Out of the subdivision goes the total of the lubrication system cost. The cost of cooling the lubricant is included under Subdivision 24.

SUBDIVISION 24

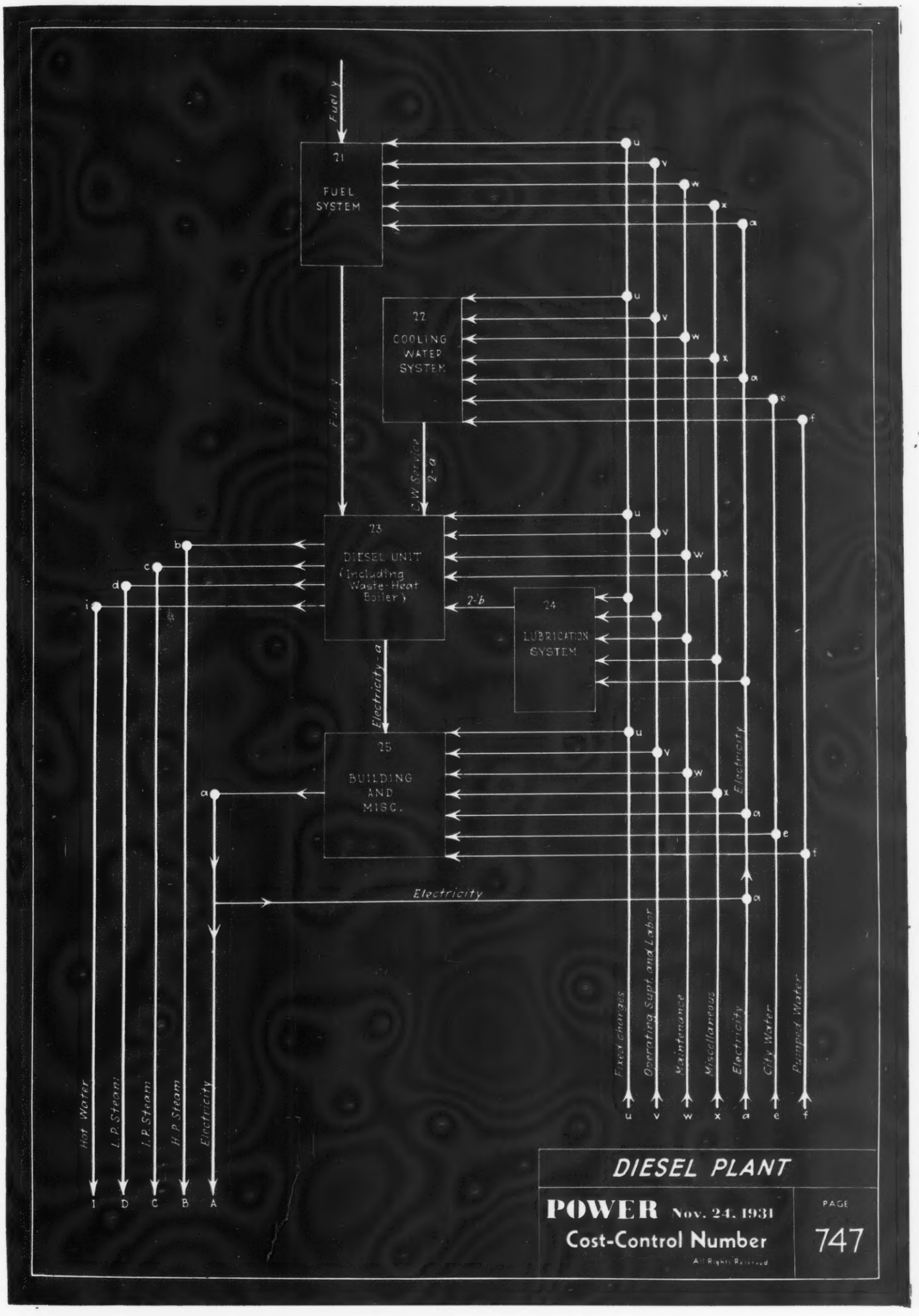
Diesel Unit: Into the diesel unit goes the cost estimates from Subdivisions 21, 22 and 23, together with the various items of labor, maintenance, fixed charges and miscellaneous. Out of the unit goes electricity and hot water. In certain plants high- or low-pressure steam may be obtained from the exhaust heat.

SUBDIVISION 25

Building and Miscellaneous: As laid out, the electricity generated by the diesel goes to the building subdivision, while the hot water and steam pass directly to the factory. This charges electricity with all of the building costs, on the basis that electricity is the main plant output. The building also bears its fixed charges, maintenance, operating labor and miscellaneous items. In some plants when jacket water or steam generated by engine exhaust is used to heat the building the engine should be credited with this heat and the building charged with it. Electricity for auxiliary use is taken off after it has accumulated building charges and is charged against the subdivisions at the unit cost.

			21 Fuel System			22 Cooling Water System			23 Diesel Unit			24 Lubrication System			25 Building and Miscellaneous			Total			Net			Unit Cost	
	GOING IN	Unit	Q	S	¢	Q	S	¢	Q	S	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	$	¢
u	Fixed Charges			45			45			1,191			18			283			1,582			1,582			
v	Operating Sup. and Labor			13			13			1,254			26			13			1,319			1,319			
w	Maintenance			5			10			500			5			56			576			576			
x	Miscellaneous			1			3			10			276			5			295			295			
y	Fuel	1,000 gal.	50	2500					50	2572								50	5,072		50	2,500		50	
a	Electricity	100 kw-hr.	72	8		72	80					2	2		5,030	5,316		5,1112	5,406						
e	City Water	1,000 lb.				1,400	28								500	10		1,900	38		1,900	38			02
f	Pumped Water	1,000 lb.				70,000	1,400											70,000	1,400		70,000	1,400			02
2a	Cooling Water Service									1,579									1,579						
2b	Lubrication Service									327									327						
	Total In			2,572			1,579			7,433			327			5683			17,594			7,710			
	GOING OUT																								
A	Electricity								5,000	5,283					5,000	5,683		10,000	10,966		4,888	5,560		1	11
I	Hot Water	1,000 lb.							70,000	2,150								70,000	2,150		70,000	2,150			03
y	Fuel	1,000 gal.	50	2,572														50	2,572						
2a	Cooling Water Service						1,579												1,579						
2b	Lubrication Service												327						327						
	Total Out			2,572			1,579			7,433			327			5683			17,594			7,710			

The round numbers inserted in the above table are designed solely to illustrate its application. They should not be taken as representative of either good or typical practice.



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ENGINE OR TURBINE PLANT

THIS CHART and form are designed for a plant that includes all types of steam generating units: condensing turbines (bleeding and non-bleeding), non-condensing turbines (bleeding and non-bleeding), mixed-pressure turbines, condensing and non-condensing engines. The inclusion of three "units" or "groups" provides for that many combinations (see Subdivision 31). More may be added if desired. Each of these may consist of one unit or of several similar units, according to the accounting necessities of the case.

SUBDIVISION 31

Unit or Group I: This may be any one of the units mentioned above or a group of several similar units. Steam may be received at one or two different pressures and exhausted at one or two different pressures (not including condenser pressure). With each unit or group of units are included all auxiliaries serving them individually. Electricity required for these auxiliaries enters from the line pooling all generation, so that net electricity delivered by a unit or group is its total output indicated at the left minus that delivered to its auxiliaries. Since all electricity generated is pooled, it goes to all auxiliaries at a single unit cost.

Aside from electricity, the unit or group will deliver one, two or all of the following: condensate, intermediate-pressure steam, low-pressure steam. It is generally sound practice to value the intermediate-pressure and low-pressure steam at the actual cost of the equivalent high-pressure steam. Where an engine or turbine exhausts or bleeds to the intermediate- or low-pressure steam line it removes from the steam slightly more than the heat equivalent of the power produced. In general, refined calculations are not worth while here, and it is sufficient to allow a net steam consumption of four pounds per kilowatt-hour generated regardless of the steam rate of the prime mover.

Thus if 120,000 kw.-hr. is generated in a back-pressure unit and 3,500,000 lb. of steam in all are supplied over the same period and at a unit cost of $0.40 per thousand pounds the total value of incoming steam is 3,500 × $0.40 = $1,400. The incoming steam equivalent of the heat removed by the unit will be 120,000 × 4 = 480,000 lb., which has a value of 480 × $0.40 = $192. Thus the net value of the exhaust steam is $1,400 — $192 = $1,208. The unit cost of exhaust steam depends upon the method of computing its total quantity. If moisture is included the weight is equal to that of the live steam, in this case 3,500,000 lb. The unit cost would then be $1,208 ÷ 3,500 = $0.345 per 1,000 lb. The weight of dry steam may be found by subtracting the moisture determined by measuring the discharge from the separator or by thermodynamic computations. Separate discharge may be estimated in some cases or determined by a counter placed on a trap of the intermittent type. Since the moisture content is small, there is no great objection to estimating it roughly or even overlooking it entirely. Whether moisture is considered or not, the same total value goes out with the exhaust steam.

Where steam is bled at one or two points from a condensing or non-condensing turbine it is necessary to divide the total power generated into the portions generated by each part of the steam (for example, steam going to first bleed point, steam to second bleed point, etc.). The power developed by each portion is used as indicated in the preceding example.

Before this plant can be analyzed the master accounting form will have been completed. From it the unit costs of electricity and high- and low-pressure steam are obtained.

SUBDIVISIONS 32 AND 33

Unit or Groups II and III: See 31.

SUBDIVISION 35

Building and Miscellaneous: It is obvious that the costs added in Subdivision 35 must be distributed over the services that leave the plant through it. The services entering and leaving 35 may be electricity, intermediate-pressure steam, low-pressure steam and condensate. More often, however, it will be electricity plus one or two of the others. Building costs may be distributed equally over these services or they may all be charged against the main plant service. In the examples presented this latter method has been arbitrarily followed.

	GOING IN	Unit	31 Group I Q	31 Group I $	31 Group I ¢	32 Group II Q	32 Group II $	32 Group II ¢	33 Group III Q	33 Group III $	33 Group III ¢	34 Miscellaneous Auxiliaries Q	34 Miscellaneous Auxiliaries $	34 Miscellaneous Auxiliaries ¢	35 Building and Miscellaneous Q	35 Building and Miscellaneous $	35 Building and Miscellaneous ¢	Total Q	Total $	Total ¢	Net Q	Net $	Net ¢	Unit Cost $	Unit Cost ¢
u	Fixed Charges			1,000			550			300			60			350			2,260			2,260			
v	Operating Sup. and Labor			200			150			150						30			530			530			
w	Maintenance			50			25			10			10			45			140			140			
x	Miscellaneous			10			10			10			5			20			55			55			
a	Electricity	100kw-hr.	300	150		130	65		42	21		15	7		15,915	8,054		16,402	8,297			—			
b	High-Pressure Steam	1,000 lb.	12,000	6,000		13,500	6,750		1,800	900								27,300	13,650		27,300	13,650			50
c	Intermed-Press. Steam	1,000 lb.													160	76		160	76						
	Total In			7,410			7,550			1,391			82			8,575			25,008			16,635			
	GOING OUT																								
a	Electricity	100kw-hr.	10,000	4,970		4,500	1,700		1,400	1,355			21		15,900	8,575		31,800	16,621		15,398	8,324			50
c	Intermed-Press. Steam	1,000 lb.	5,000	2,300									21					5,000	2,321		4,840	2,245			46
d	Low-Pressure Steam	1,000 lb.				13,500	5,850						20					13,500	5,870		13,500	5,870			43
K	Condensate	1,000 lb.	7,000	140					1,800	36			20					2,500	196		8,800	196			02
	Total Out			7,410			7,550			1,391			82			8,575			25,008			16,635			

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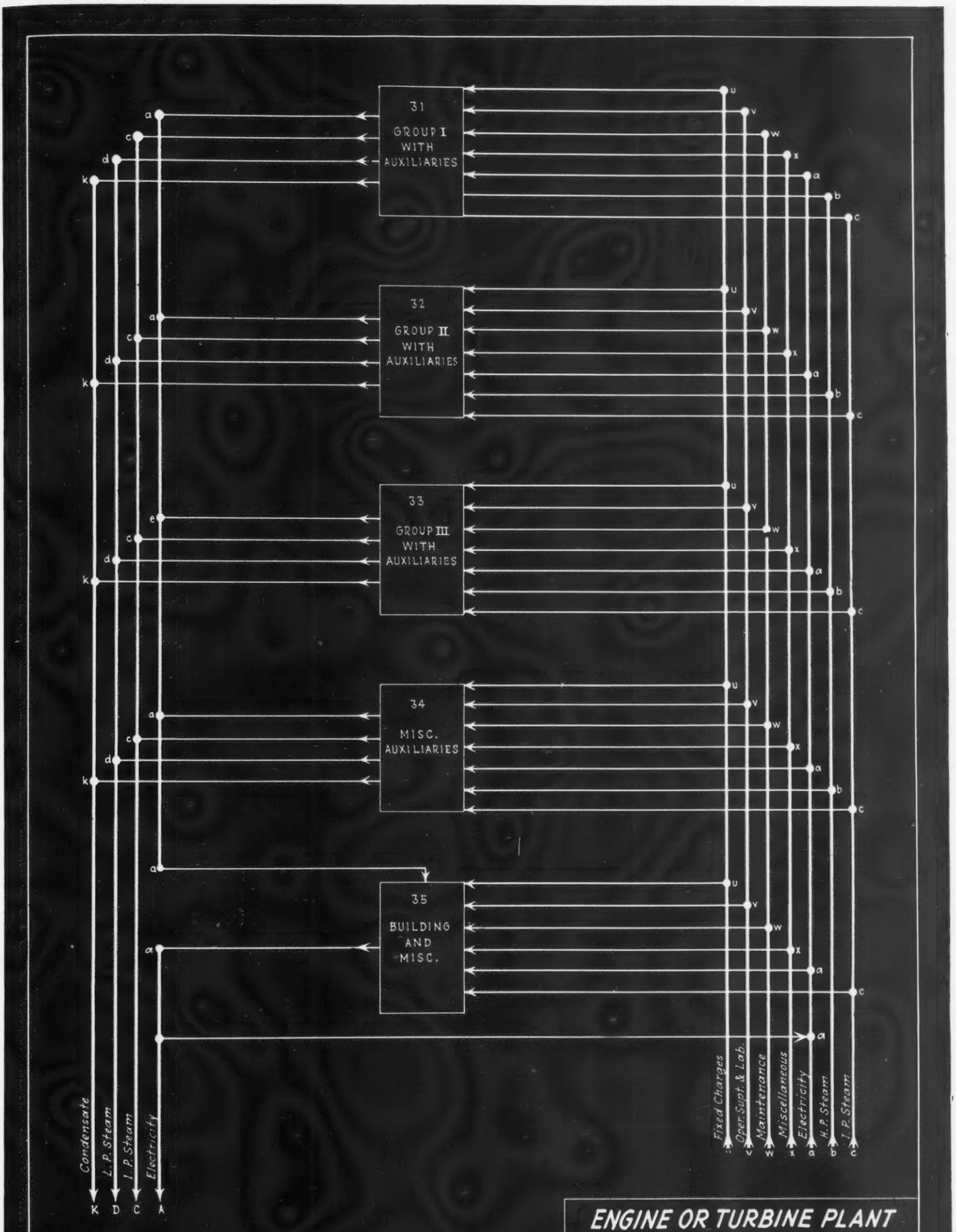

ENGINE OR TURBINE PLANT

POWER Nov. 24, 1931
Cost-Control Number

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ENGINE OR TURBINE UNIT

IT MAY be found desirable to analyze the operating cost of the engine or turbine plant in greater detail than was done in the previous article. The chart and accounting form here presented are designed to permit individual analysis of the costs involved in each of Subdivisions 31 to 33 of the previous article. For this purpose this unit consists of an engine- or turbine-driven generator, its various and necessary auxiliaries and the building. As in the case of the engine or turbine plant, the steam-electric generating unit may be condensing or non-condensing, either bleeding, non-bleeding or mixed-pressure.

SUBDIVISION 31

Condenser and Auxiliaries: Where the prime mover, 33, is a turbine or engine operating condensing, 31 consists of the condenser, the circulating water pumps, as well as the condensate and air pumps. It will be assessed with the fixed capital charges on the above equipment and operating labor, maintenance, and the miscellaneous. If the auxiliaries and pumps are motor-driven, it receives electricity. This subdivision also receives steam exhaust from the turbine or engine, Subdivision 33. This steam has no value except to provide condensate for boiler feeding and can be charged for on that basis.

The unit value of condensate to the boiler room is the unit cost of make-up, and seems a reasonable basis upon which to credit the engine or turbine plant or factory for condensate returned.

SUBDIVISION 32

Miscellaneous Auxiliaries: This group includes equipment not considered in the individual prime mover unit or its condenser. Such equipment would include separately driven exciters, house turbines with their auxiliaries, general turbine room instruments which are not included on the individual units, air compressors, and engine room crane. This group receives the charges for steam and electricity from their respective pools.

SUBDIVISION 33

Turbine- or Engine-Driven Generator: In addition to the prime mover and generator, this group includes the lubricating oil system with coolers and purifiers, generator air-cooling system and such piping and instruments as apply particularly to the prime mover.

This plant receives, in addition to the usual fixed operating and maintenance charges, high-pressure steam for the turbine or engine and the cost of condenser service, line *3A*.

SUBDIVISION 34

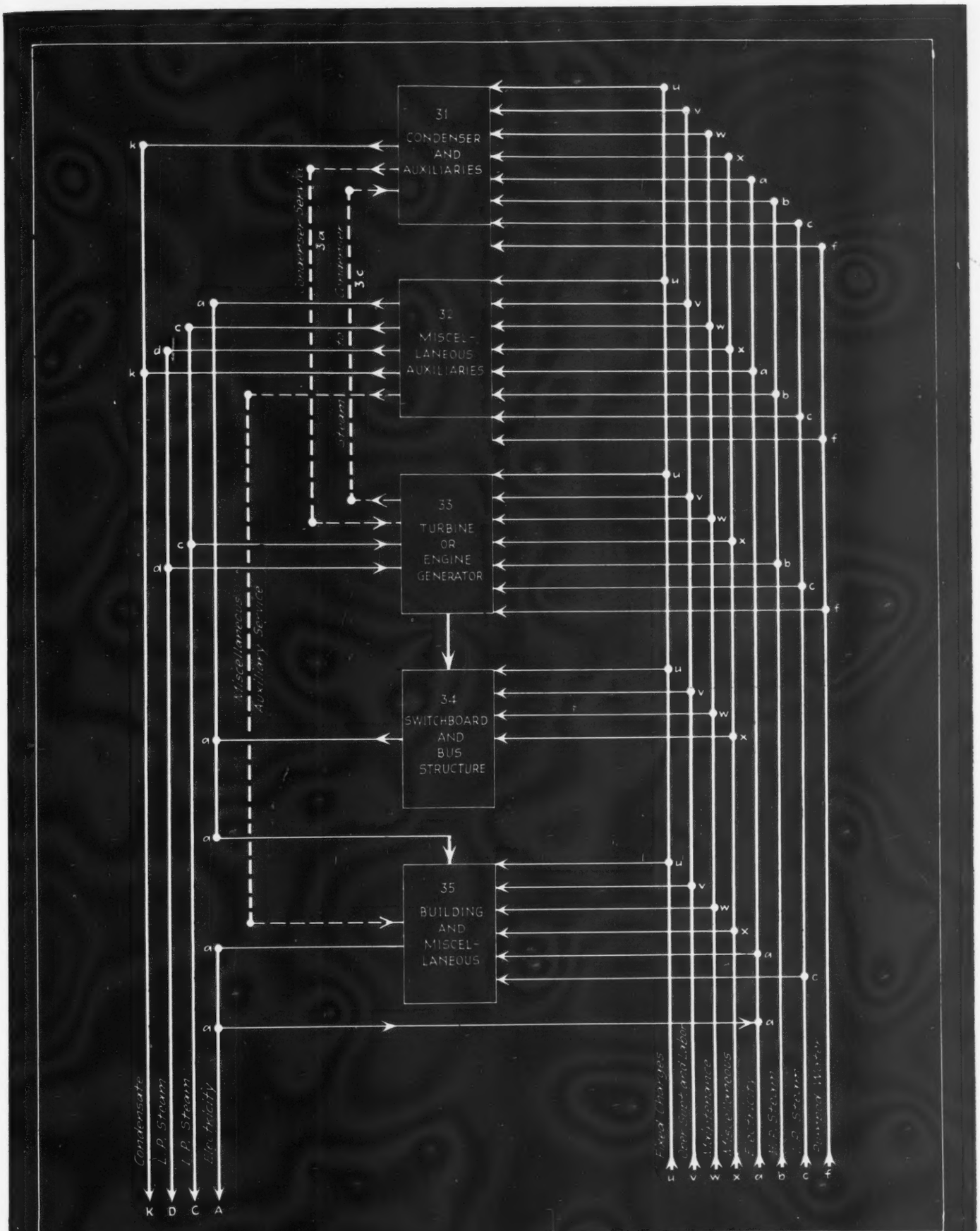
Switchboard and Bus Structure: This group comprises the generator switchboard and the bus structure, with its main and auxiliary switching control and protective equipment, ending with the outgoing feeders.

SUBDIVISION 35

Building and Miscellaneous: The charges pertaining to the building proper are added in this group. The electricity, with all of the costs collected in passing through the previous groups, 31 to 34, is considered as an input to the building.

			31 Condenser and Auxiliaries			32 Miscellaneous Auxiliaries			33 Turbine or Engine Unit			34 Switch Board and Bus Structure			35 Building and Miscellaneous			Total			Net			Unit Cost	
	GOING IN	Unit	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	$	¢
u	Fixed Charges			150			103			750			285			160			1,448			1,448			
v	Operating Sup. and Labor			75			30			470			160			30			765			765			
w	Maintenance			30			10			100			70			5			215			215			
x	Miscellaneous			25			5			85			65						180			180			
a	Electricity	100 kw.-hr.	1,100	1,060		4	4					7,200	6,120		7,206	6,706		15,510	13,890						
b	High-Pressure Steam	1,000 lb.				35	14		8,650	3,500									3,514		8,685	3,514			.405
c	Intermed.-Press. Steam	1,000 lb.																							
f	Pumped Water	1,000 lb.					12		50	5									17		170	17			.10
3a	Condenser Service									1,340									1,340						
3b	Misc. Aux. Service															167			167						
	Steam to Condenser	1,000 lb.		130															130						
	Total In			1,470			178			6,250			6,700			7,068			21,666			6,139			
	GOING OUT																								
A	Electricity	100 kw.-hr.							7,200	6,120		7,200	6,700		7,200	7,068		21,600	19,888		6,090	5,988			.985
C	Intermed.-Press. Steam	1,000 lb.																							
D	Low-Pressure Steam	1,000 lb.				35	11												11		35	11			.314
3b	Misc. Aux. Service						167												167						
K	Condensate	1,000 lb.	8,650	130															130		8,650	130			.015
3a	Condenser Service			1,340															1,340						
	Steam to Condenser	1,000 lb.								130									130						
	Total Out			1,470			178			6,250			6,700			7,068			21,666			6,139			

The round numbers inserted in the above table are designed solely to illustrate its application. They should not be taken as representative of either good or typical practice.



ENGINE OR TURBINE UNIT

BOILER PLANT

THE CHART and form on this page are designed to allow the segregation and analysis of the charges pertaining to the boiler plant. This plant consists principally of the boilers with their furnaces and fuel-firing equipment, together with the other auxiliaries, such as fuel-preparation, make-up and feed-water systems, and fans and ash-handling equipment, necessary to the operation of the boiler units. These subdivisions receive various services from the pools, and, in turn, discharge certain of the various power services to the pools.

SUBDIVISION 51

Fuel Preparation: Fuel enters the plant at this subdivision, and fixed charges, operating labor, maintenance and miscellaneous charges incidental to its preparation and handling are added to the fuel cost in this subdivision, as is also the necessary electricity for operating conveying and other preparation equipment.

SUBDIVISION 52

Make-Up, Treatment, Evaporation: Make-up water enters the system in this subdivision, where it is pumped to the required pressure and treated. Make-up may be either city water or pumped water, and this subdivision may receive steam either for pumping, evaporation or treatment.

SUBDIVISION 53

Feed System: Receives the condensate returning from the turbine plant and the treated make-up. In addition to its portion of the fixed and operating charges, additional costs are incurred here, due to the use of steam at either one or several pressures for water heating, and electricity or steam for pumping.

SUBDIVISION 54

Fans: Includes the flues, stack and fans, both forced and induced, necessary to the operation of the furnace firing equipment. The principal output of this subdivision is fan service, which is supplied directly to the furnace and firing equipment.

SUBDIVISION 55

Ash Handling: Includes the equipment necessary to handle the ashes from all of the boilers. Its input is fixed, operating and maintenance charges, as well as either steam or electricity service for operating ash sluice pumps. In addition, this group receives pumped water for ash sprays and similar uses.

SUBDIVISION 56

Firing Equipment and Furnaces: Includes the boiler furnaces and firing equipment, which may be either stokers, fuel oil burners and piping, or pulverized-coal burners and piping. Coal pulverizers and transports, as well as fuel oil heaters and pumps, would be included under 51. The output from this subdivision, as shown on the chart, is termed "furnace heat," and enters the boilers, 57.

SUBDIVISION 57

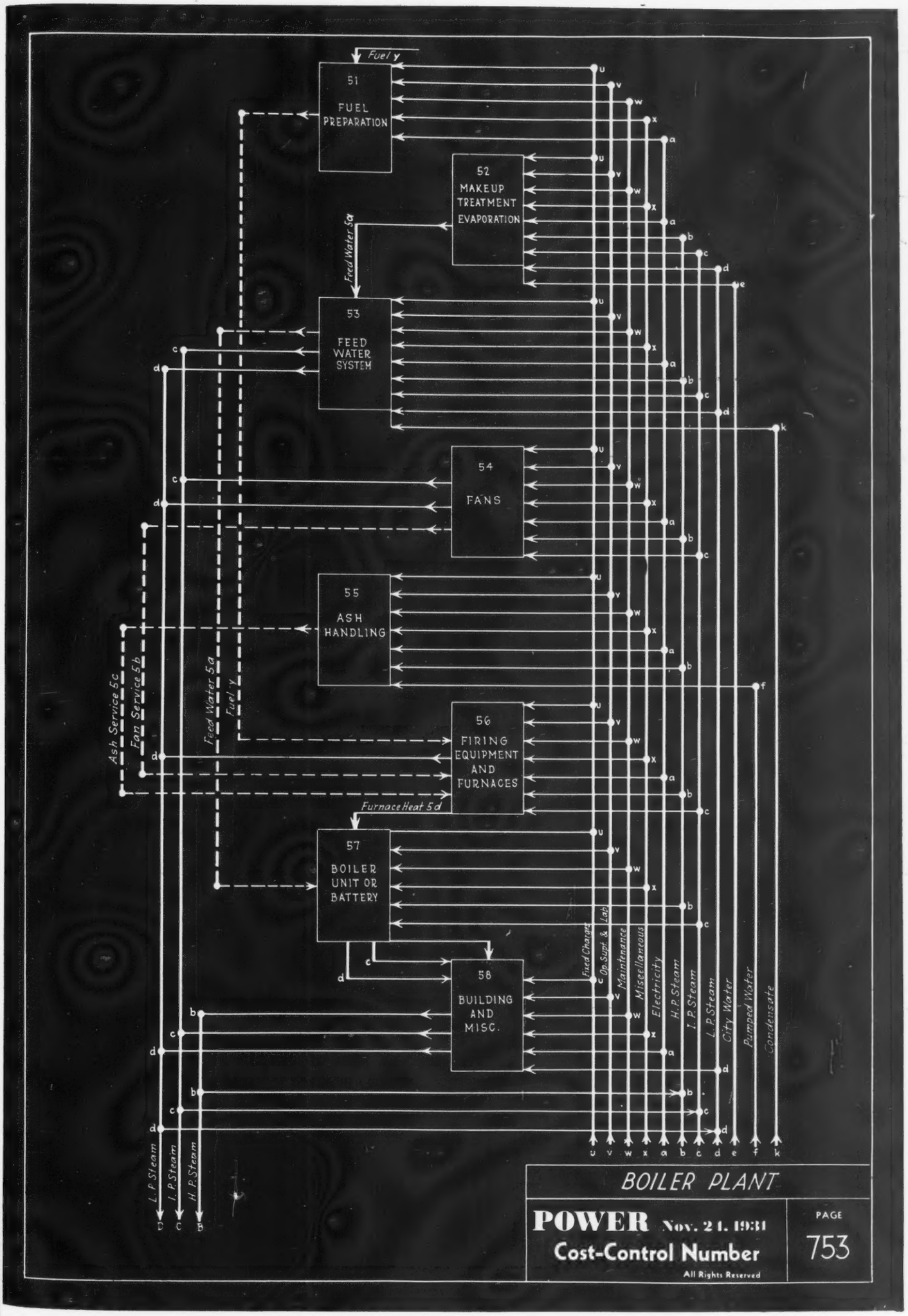
Boiler—Unit or Battery: This includes the boilers proper, together with furnace water walls, superheaters and economizers, air preheaters, and steam piping.

SUBDIVISION 58

Building and Miscellaneous: The steam generated in the equipment of 57, carrying all the charges from 51-57, discharges through the building.

	GOING IN	Unit	51 Fuel Preparation Q	51 $	51 ¢	52 Makeup Treatment Q	52 $	52 ¢	53 Feed Water System Q	53 $	53 ¢	54 Fans Q	54 $	54 ¢	55 Ash Handling Q	55 $	55 ¢	56 Firing Equip. and Furnaces Q	56 $	56 ¢	57 Boiler Unit or Battery Q	57 $	57 ¢	58 Building and Miscellaneous Q	58 $	58 ¢	Total Q	Total $	Total ¢	Net Q	Net $	Net ¢	Unit Cost $	Unit Cost ¢
u	Fixed Charges			100			60			380			90			40			880			1,200			250			3,000			3,000			
v	Operating Sup. and Labor			150			50			100			50			100			550			100			40			1,140			1,140			
w	Maintenance			40			20			130			30			40			600			100			50			1,010			1,010			
x	Miscellaneous			50			10			60			20			20			170			20						350			350			
y	Fuel	1,000 lb.	5,340	10,000														5,340	10,310								10,680	20,310		5,340	10,000		1	87
a	Electricity	100 kw-hr.	25	30		4	5		180	200		270	310		22	25		21	24					2	2		524	596		524	596		1	14
b	High-Pressure Steam	1,000 lb.																						43,200	19,094		43,200	19,094						
c	Intermed.-Press. Steam	1,000 lb.																																
d	Low-Pressure Steam	1,000 lb.							6,500	2,500																	6,500	2,500		6,500	2,500			385
e	City Water	1,000 lb.				4,500	70					625	10														5,125	80		5,125	80			0156
f	Pumped Water	1,000 lb.																																
k	Condensate	1,000 lb.							40,000	760																	40,000	760		40,000	760			019
5a	Feed Water	1,000 lb.							4,500	215											44,500	4,345					49,000	4,560						
5b	Fan Service																		510									510						
5c	Ash Service																		225									225						
5d	Furnace Heat																					13,329						13,329						
	Total In			10,370			215			4,345			510			225			13,329			19,094			19,436			67,524			19,436			
	GOING OUT																																	
B	High-Pressure Steam	1,000 lb.																			43,200	19,094		43,200	19,436		86,400	38,530		43,200	19,436			45
C	Intermed.-Press. Steam	1,000 lb.																																
D	Low-Pressure Steam	1,000 lb.																																
5a	Feed Water	1,000 lb.				4,500	215		44,500	4,345																	49,000	4,560						
5b	Fan Service												510															510						
5c	Ash Service															225												225						
5d	Furnace Heat																		13,329									13,329						
y	Fuel	1,000 lb.	5,340	10,370																							5,340	10,370						
	Total Out			10,370			215			4,345			510			225			13,329			19,094			19,436			67,524			19,436			

The round numbers inserted in the above table are designed solely to illustrate its application. They should not be taken as representative of either good or typical practice.



BOILER PLANT

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WATER-PUMPING PLANT

THIS PLANT may be a large pumping station, such as would supply water to a city or town, or it may consist of the general service pumps in an industrial or utility power plant. The same accounting analysis, however, can be made for either type of plant. In the large pumping station it may be desirable to make a detailed analysis of the pump prime movers. For this purpose the accounting forms and charts made for the diesel engine or turbine unit may be applied. The cost of pumped water is materially affected by the cost of the water supply. If it must be purchased from city supply the cost of the pumped water is greatly increased over what it would be if obtained from a local source.

SUBDIVISION 71

Internal-Combustion Unit: Comprises the pump, prime mover and its auxiliaries and associated piping. The subdivision receives fuel for the internal-combustion engine, fixed charges, operating superintendence and labor, maintenance, miscellaneous, and in addition the cost of the water supplied to the pump. Where intake construction or wells are necessary the fixed charges on its initial cost should be included.

SUBDIVISIONS 72 AND 73

Steam Engine and Turbine Units: Both of these subdivisions receive high- or intermediate-pressure steam in addition to fixed charges, operating superintendence and labor, maintenance and miscellaneous charges. The output in addition to pumped water may be intermediate- or low-pressure steam. Under miscellaneous may be included such items as lubrication and waste.

SUBDIVISION 74

Motor Unit: This subdivision receives electricity service instead of high- or low-pressure steam, the other charges being similar to those of Subdivisions 72 and 73.

SUBDIVISION 75

Building and Miscellaneous: Against the building are placed the fixed charges of the building structure or that part of the building that houses the pumping equipment, as well as the charges due to general piping and intake works that have not been included under the other subdivisions. It is also charged with electricity for building lighting, steam for heating, miscellaneous supplies and janitor service, etc. As in the other charts, the main output, pumped water, has been run through the building so that the costs accruing against the building subdivision will be added to the total cost of the pumped water.

	GOING IN	Unit	71 Internal Comb. Unit Q	71 $	71 ¢	72 Steam Eng Unit Q	72 $	72 ¢	73 Turbine Unit Q	73 $	73 ¢	74 Motor Unit Q	74 $	74 ¢	75 Building and Miscellaneous Q	75 $	75 ¢	Total Q	Total $	Total ¢	Net Q	Net $	Net ¢	Unit Cost $	Unit Cost ¢
u	Fixed Charges									35			30			10			75			75			
v	Operating Sup. and Labor									25			25			2			52			52			
w	Maintenance									5			5			0			10			10			
x	Miscellaneous									5			5			4			14			14			
y	Fuel	100 gal.																							
a	Electricity	100 kw.-hr.										105	105		2	2		107	107		107	107		1	00
b	High-Pressure Steam	1,000 lb.							270	108								270	108		270	108		0	40
c	Intermed.-Press. Steam	1,000 lb.																							
e	City Water	1,000 lb.							45,000	900		70,000	1,400					115,000	2,300		115,000	2,300		0	02
f	Pumped Water	1,000 lb.													115,000	2,594		115,000	2,594						
	Total In									1,078			1,570			2,612			5,260			2,666			
	GOING OUT																								
C	Intermed.-Press. Steam	1,000 lb.							270	54								270	54		270	54		0	20
D	Low-Pressure Steam	1,000 lb.							45,000	1,024		70,000	1,570		115,000	2,612		230,000	5,206		115,000	2,612		0	0227
	Total Out									1,078			1,570			2,612			5,260			2,666			

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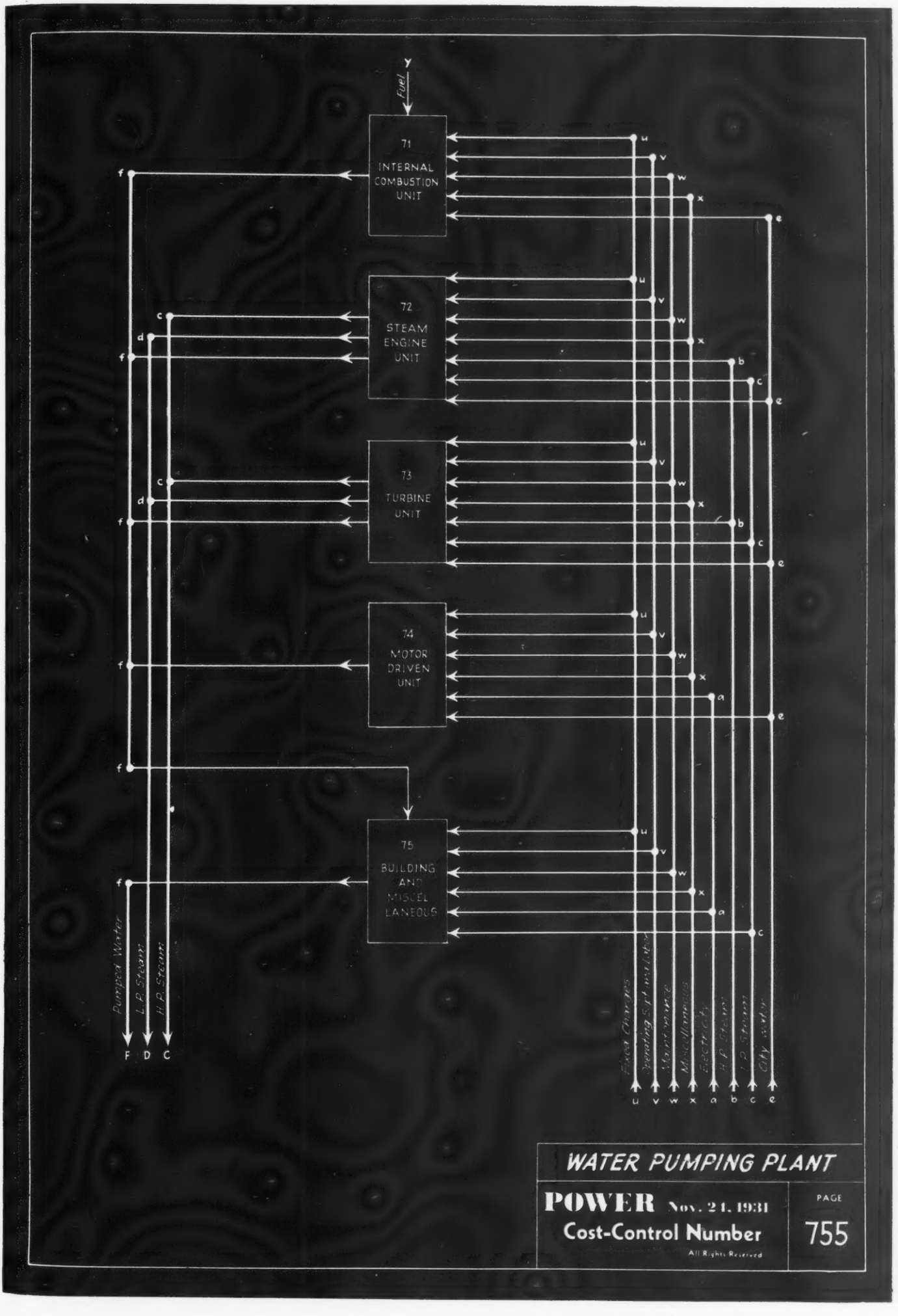

WATER PUMPING PLANT

POWER Nov. 24, 1931
Cost-Control Number

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WATER-HEATING PLANT

IN MANY PLANTS hot water is a power service of distinct importance. Large hotels, for example, require hot water in such quantities that the total cost may run into the tens of thousands of dollars yearly—for guest rooms, kitchens and laundries particularly. All such applications should be metered and charged as an incentive to saving and as a means of getting correct costs. Some plants charge for hot water, but include in the cost only water and steam. Transformation of steam and cold water into hot water requires equipment with resulting fixed charges, operating labor and supervision, maintenance and miscellaneous charges. In addition electricity or steam is sometimes required for pumping.

SUBDIVISION 81

Waste Fuel Water Heater: Many plants recover some useful heat from a furnace burning waste paper, diesel engine exhaust, wood chips or other industrial wastes. The warm water from this heater may or may not pass through the steam heaters for further rise in temperature. The former arrangement is the more common, as it permits better control of final temperature.

In addition to waste fuel this subdivision receives fixed, operating superintendence and labor, maintenance, and miscellaneous charges.

SUBDIVISION 82

Steam Water Heater: Receives steam at any pressure and either city water or (outside) pumped water. If pumps are part of the hot water plant electricity or steam may be required to drive them. Separation of 81 and 82 clearly reveals any saving in steam in 82 made possible by the use of more waste fuel (or its more efficient use) in 81.

SUBDIVISION 83

Building and Miscellaneous: The division corresponds to that of the same name in other plants. It should be pointed out that where heaters are (as usual) in a building with other power equipment they still occupy space and are therefore responsible for some portion of the building costs. In general this subdivision should include the piping and meters in the hot water lines up to the point of application, or at least up to the wall of the factory departments.

	GOING IN		81 Waste Fuel Water Heaters			82 Steam Water Heaters			83 Building and Miscellaneous			Total			Net			Unit Cost	
		Unit	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	$	¢
u	Fixed Charges			120			150			50			320			320			
v	Operating Sup. and Labor			200			50			50			300			300			
w	Maintenance			20			10			40			70			70			
x	Miscellaneous			10			10			20			40			40			
y	Waste Fuel			50									50			50			
a	Electricity	100kw.-hr.				30	30		10	10		40	40			40		1	00
b	High-Pressure Steam	1,000 lb.				2,000	1,000					2,000	1,000			1,000		0	50
c	Intermed-Press. Steam	1,000 lb.				5,000	2,000					5,000	2,000			2,000		0	40
d	Low-Pressure Steam	1,000 lb.				4,000	1,000					4,000	1,000			1,000		0	25
e	City Water	1,000 lb.	75,000	1,500			-						1,500			1,500		0	02
f	Pumped Water	1,000 lb.																	
i	Hot Water	1,000 lb.					1,900			6,150			8,050						
	Total In			1,900			6,150			6,320			14,370			6,320			
	GOING OUT																		
I	Hot Water	1,000 lb.	75,000	1,900		75,000	6,150		75,000	6,320		225,000	14,370		75,000	6,320		0	084
	Total Out			1,900			6,150			6,320			14,370			6,320			

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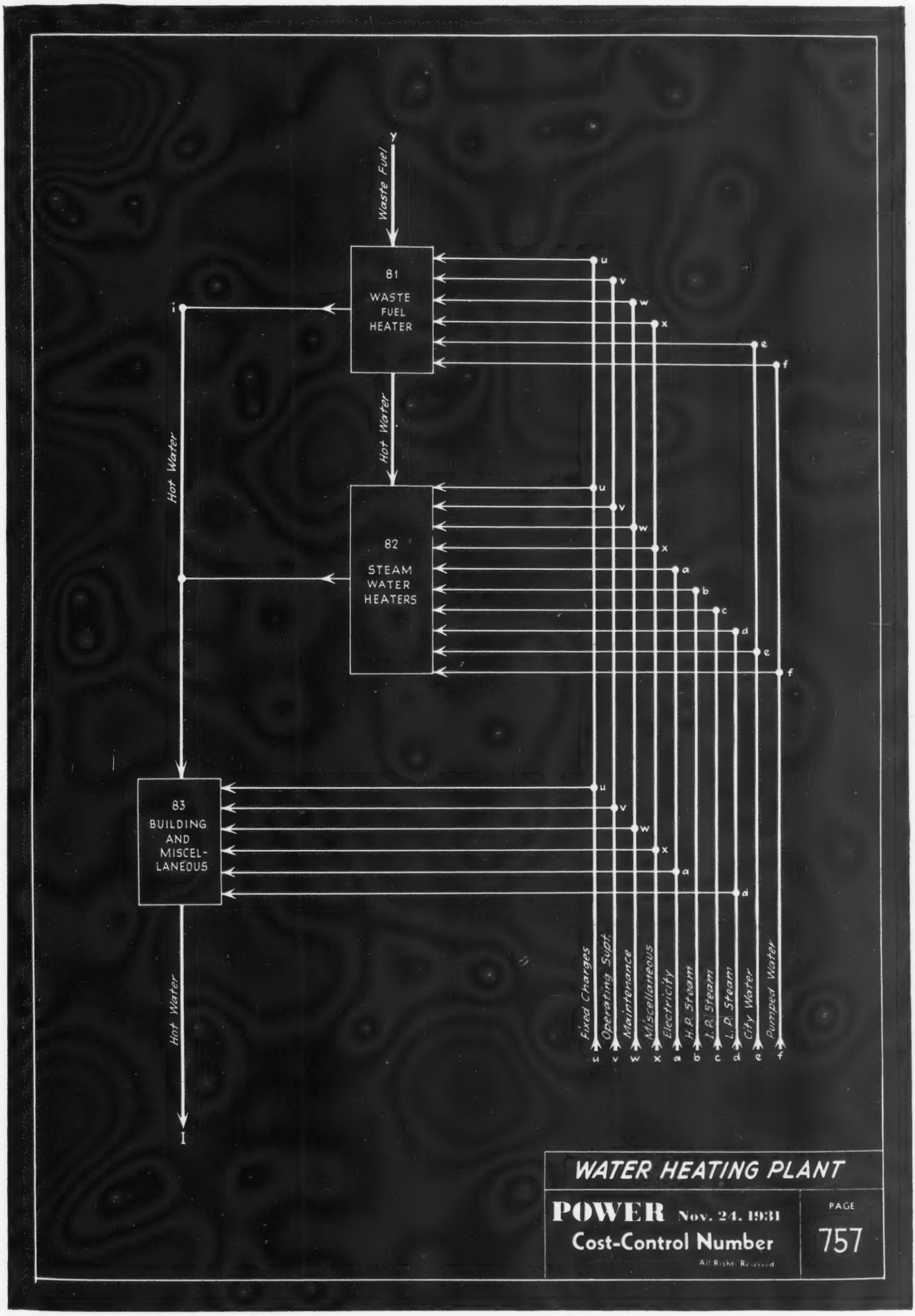

WATER HEATING PLANT

POWER Nov. 24, 1931

Cost-Control Number

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PAGE 757

AIR-COMPRESSING PLANT

IN AN INDUSTRIAL power plant air-compressing service to the factory may assume such proportions as to make analysis of the compressor plant profitable. Such a plant would probably contain a number of compressors, which may be driven by the same type of prime mover or by different types. The chart and accounting form below illustrate the latter type of plant, containing four compressors, driven, respectively, by internal-combustion engine, steam engine, turbine and motor. The discharge pressure of each unit is assumed to be the same, all units delivering to a common plant header. The costs given in the accounting form are for a plant having steam engine and motor-driven compressors.

SUBDIVISION 91

Cooling-Water System: Cooled water is delivered by this subdivision to the jacket, and inter- and aftercoolers of each air compressor. It comprises cooling towers or spray ponds, pumps, piping and fittings upon which fixed charges are calculated and charged to the cooling-water system. Electricity for pumping and city water or pumped water for make-up are the only services entering this subdivision, the other charges being operating superintendence and labor, maintenance and miscellaneous. The water in the system circulates from the cooling system to the compressor and back again and therefore has been left out of the accounting. A unit cost is determined for the cooled water and is based upon the amount of water used.

SUBDIVISION 92

Internal-Combustion Unit: Receives fuel and cooling water from Subdivision 91. Against it is also charged operating labor, maintenance, fixed charges and miscellaneous. Lubrication is one of the cost items included under miscellaneous in this and Subdivisions 93, 94 and 95.

SUBDIVISION 93

Steam Engine Unit: This unit may receive either high- or intermediate-pressure steam, together with the other charges given under Subdivision 92, excepting fuel. Its output in addition to compressed air may be intermediate- or low-pressure steam exhaust from the engine.

SUBDIVISION 94

Turbine Unit: The input and output charges for this unit are similar to those of Subdivision 93.

SUBDIVISION 95

Motor Unit: Electricity and cooling water are the only power services chargeable to this unit. Fixed charges, operating superintendence and labor, maintenance and miscellaneous also are added to the cost of the compressed-air output.

SUBDIVISION 96

Building and Miscellaneous: The compressed-air output of all of the compressor units is delivered to and discharged from this subdivision in order that the charges associated with the building housing this equipment may be added to the total cost of the compressed-air service before it is delivered to the factory. It is also convenient to include here the fixed charges on such items as general plant piping, together with the cost of its maintenance. The fixed charges of each unit should, however, include the cost of piping associated with it.

	GOING IN	Unit	91 Cooling Water System Q	91 $	91 ¢	92 Internal Comb. Unit Q	92 $	92 ¢	93 Steam Eng Unit Q	93 $	93 ¢	94 Turbine Unit Q	94 $	94 ¢	95 Motor Unit Q	95 $	95 ¢	96 Building and Miscellaneous Q	96 $	96 ¢	Total Q	Total $	Total ¢	Net Q	Net $	Net ¢	Unit Cost $	Unit Cost ¢
u	Fixed Charges			20						40						25			30			115			115			
v	Operating Sup. and Labor			20						20						20			10			70			70			
w	Maintenance			10						15						10			5			40			40			
x	Miscellaneous			10						10						10			10			40			40			
y	Fuel	100 gal																										
a	Electricity	100 kw-hr	10	10											88	88		5	5		103	103		103	103		1	00
b	High-Pressure Steam	1,000 lb							250	100											250	100		250	100		0	40
c	Intermed.-Press. Steam	1,000 lb																										
e	City Water	1,000 lb	50	1																	50	1		50	1		0	02
f	Pumped Water	1,000 lb																										
h	Compressed Air	1,000 cu ft																3,800	359		3,800	359						
9a	Cooling Water Service	1,000 cu ft								30						41						71						
	Total In			71						215						194			419			899			469			
	GOING OUT																											
9a	Cooling Water Service			71																		71						
C	Intermed.-Press. Steam	1,000 lb																										
D	Low-Pressure Steam	1,000 lb							250	50											250	50		250	50		0	20
H	Compressed Air	1,000 cu ft							1600	165					2,200	194		3,800	419		7600	778		3,800	419		0	11
	Total Out			71						215						194			419			899			469			

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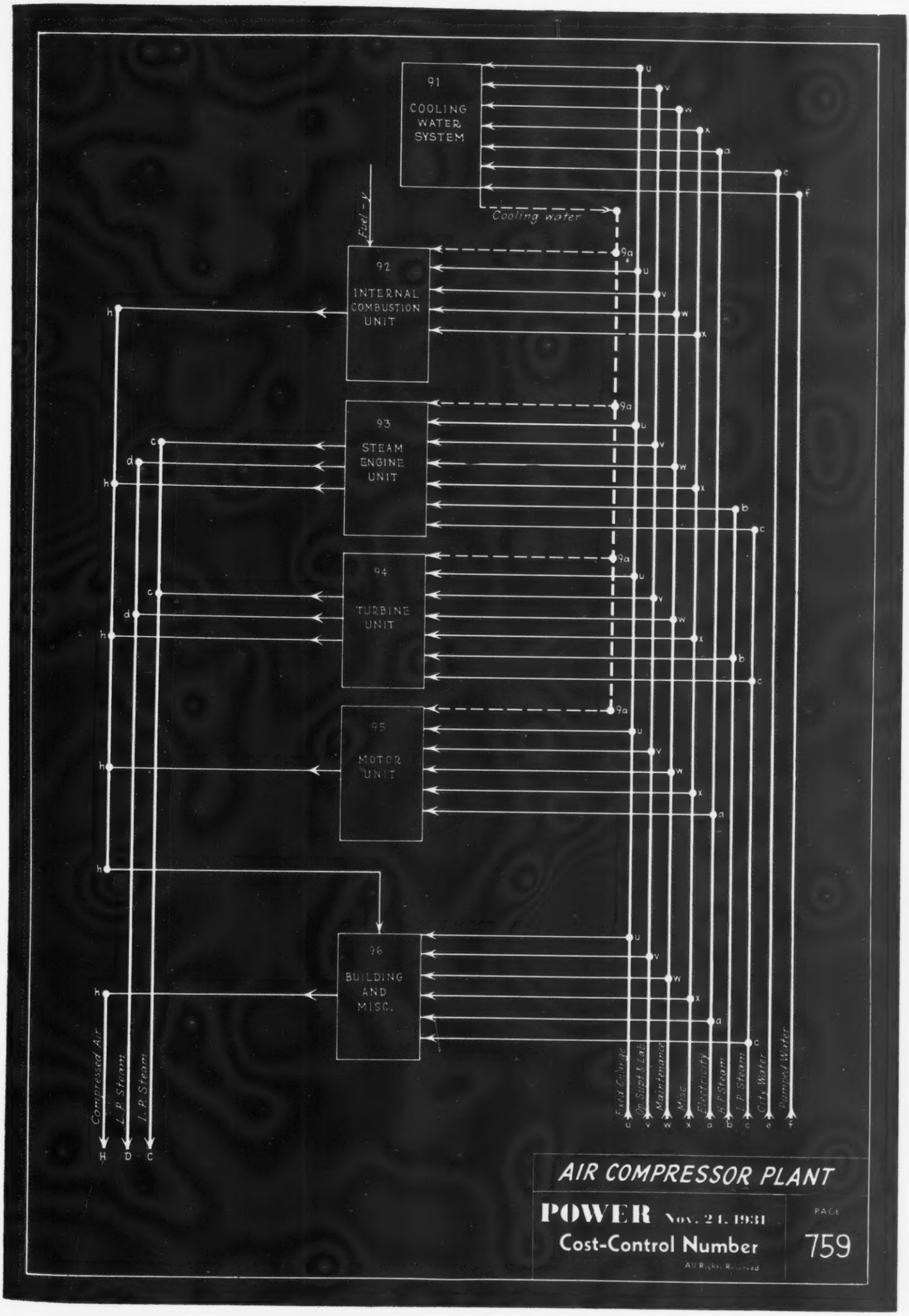

AIR COMPRESSOR PLANT

POWER Nov. 24, 1931
Cost-Control Number

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COMPRESSOR REFRIGERATION PLANT

WHILE it is customary in refrigerating plants to lump all costs and so ascertain the total unit cost, a more accurate analysis may be obtained by separating the plant into its several subdivisions as shown in the chart. The chart covers a single-pressure plant, but a dual-pressure plant layout may be obtained by the addition of a second compressor or compressor subdivision. To obtain the various quantities involved in the plant operation, meters are needed to record the flow of power, water, ammonia, and brine—but these instruments should be in every plant. The unit of refrigeration output shown in the accounting form is tons, which refers not to the rate but to the total B.t.u. of cooling divided by 288,000.

SUBDIVISION 101

Compressor Unit: Into the compressor goes its fixed charges, operating labor, maintenance, miscellaneous and power. The outgo is high-pressure ammonia vapor to the condenser, bearing with it all these cost items. If the compressor is steam-driven, the steam input cost consists of the total cost of the steam supplied, obtainable from the master accounting form. In this case additional output from the compressor of low- or intermediate-pressure steam may exist. If this steam is used the compressor should be credited with the cost of an equivalent amount of initial steam. If an oil engine drive is employed on the compressor the cost of this power may be obtained by arriving at the cost of the several services supplied the engine. Cost of lubrication should be included under miscellaneous.

SUBDIVISION 102

Condenser: In the condenser subdivision are included the cooling tower, water pumps and ammonia receiver. Its input are the items of labor, fixed charges, maintenance, supplies, pumping costs and make-up water. Its output of liquid ammonia bears with it the total of all previous cost items.

SUBDIVISION 103

Brine Cooling: Within the plant, be it a cold-storage or an ice plant, the liquid ammonia flows to a brine cooler. This bears as its input all its local cost items plus the accumulated costs in the liquid ammonia. Electricity may be required for brine circulation and the miscellaneous item should include the cost of salt for maintaining brine concentration.

SUBDIVISION 104

Building and Miscellaneous: As a matter of handling costs, it is assumed that all the brine-cooling costs enter the building, along with the various items applying directly to the building itself, as well as such items as wash water for the locker rooms. The output is cold brine or refrigeration. This may be employed in ice-freezing, in which event an ice plant breakdown may be necessary. This plant would have its various inputs of agitation air, cam water, core-sucking, power and other items.

	GOING IN	Unit	101 Compressor Unit Q	101 Compressor Unit $	101 Compressor Unit ¢	102 Condensing Q	102 Condensing $	102 Condensing ¢	103 Brine Cooling Q	103 Brine Cooling $	103 Brine Cooling ¢	104 Building and Miscellaneous Q	104 Building and Miscellaneous $	104 Building and Miscellaneous ¢	Total Q	Total $	Total ¢	Net Q	Net $	Net ¢	Unit Cost $	Unit Cost ¢
u	Fixed Charges			125			30			50			300			505			505			
v	Operating Sup. and Labor			350			200			450			100			1,100			1,100			
w	Maintenance			25			20			25			50			120			120			
x	Miscellaneous			10			2			5			10			27			27			
y	Fuel	1,000 lb.																				
a	Electricity	100 kw.-hr.	378	756		18	36		11	22		6	12			826		413	826		2	00
b	High-Pressure Steam	1,000 lb.																				
c	Intermed.-Press. Steam	1,000 lb.																				
e	City Water	1,000 lb.				1,287	19									19			19			015
f	Pumped Water	1,000 lb.																				
10c	Vapor 1																					
10a	Vapor 2						1,266									1,266						
10b	Liquid Ammonia									1,573						1,573						
g	Refrigeration	Tons										1,500	2,125			2,125						
	Total In			1,266			1,573			2,125			2,597			7,561			2,597			
	GOING OUT																					
C	Intermed.-Press. Steam	1,000 lb.																				
D	Low-Pressure Steam	1,000 lb.																				
G	Refrigeration	Tons							1,500	2,125		1,500	2,597			4,722		1,500	2,597		1	73
10c	Vapor 1																					
10a	Vapor 2			1,266												1,266						
10b	Liquid Ammonia						1,573									1,573						
	Total Out			1,266			1,573			2,125			2,597			7,561			2,597			

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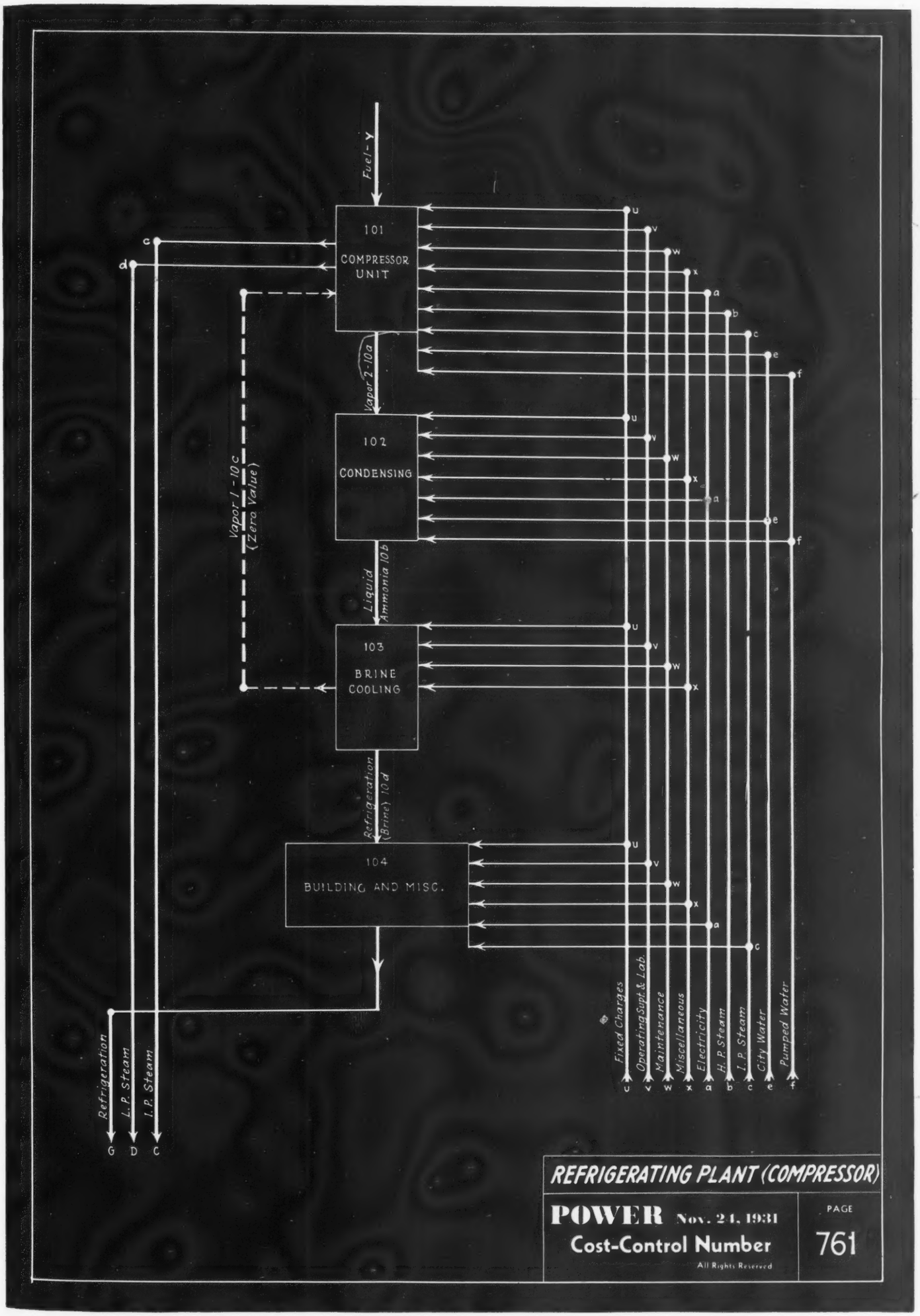

REFRIGERATING PLANT (COMPRESSOR)

POWER Nov. 24, 1931
Cost-Control Number

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ABSORPTION REFRIGERATION PLANT

THE NUMBER of absorption refrigeration plants still in operation justifies the presentation of a chart and accounting form for analyzing an absorption refrigeration plant. While engineers usually think of the system as starting at the generator, the chart begins with the absorber, which is better from the viewpoint of convenience. The adoption of the chart will enable the engineer to segregate the various cost items and detect the apparatus in which the cost is excessive. In the example the plant output is taken as 1,500 tons a month. Low-pressure steam is employed in the generator.

SUBDIVISION 101

Absorber: In the absorber the low-pressure vapor from the evaporator enters to mix with weak liquor from the generator. The costs to be assessed against the absorber are fixed-charges, labor, maintenance, miscellaneous cost of handling the water needed to remove the heat of solution, make-up water, and the cost of the power needed by the aqua pump. Out of the absorber goes the strong liquor to the generator.

Exception may be taken by some refrigerating engineers to the zero value placed against the returning weak liquor, but it may be assumed to be a fixed quantity of fluid in constant circulation with a constant heat content. Of course the absorber includes the heat exchanger.

SUBDIVISION 102

Generator: The generator includes the rectifier and the steam-coil attachments. Its input is its fixed charges, labor, maintenance, supplies, and low-pressure steam costs; the latter is obtained from the master accounting form. Its output is high-pressure ammonia vapor, which goes to the condenser carrying all previous charges.

SUBDIVISION 103

Condenser: The condenser, which includes the receiver, is charged with the cost of the vapor from the generator together with its own fixed charges, labor, maintenance, supplies, and cost of cooling water. Its output of liquid ammonia carries all the pyramided cost items.

SUBDIVISION 104

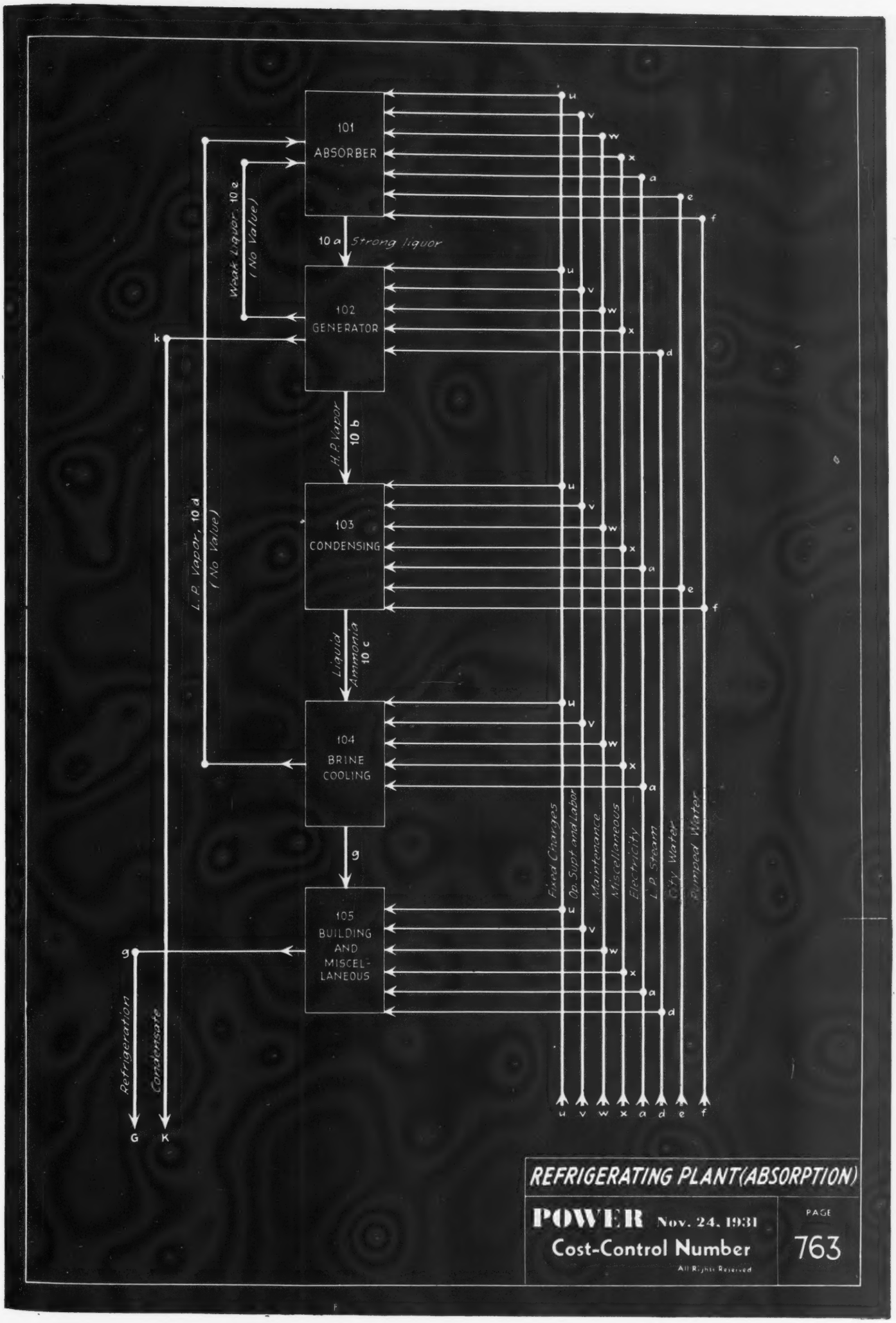
Brine Cooling: As with the compression system, the brine cooling subdivision has as its input all of the accumulated costs in the liquid ammonia plus the various cost items assessed against the brine-cooling equipment. Its output, which carries with it all the costs, is refrigeration service.

SUBDIVISION 105

Building: Into the building, as a matter of convenience, is sent the brine with its cost. In addition the building has its own cost items, which include lighting electricity, wash water and other miscellaneous items. The building output is refrigeration, which bears the cost of the plant subdivisions.

			101 Absorber			102 Generator			103 Condensing			104 Brine Cooling			105 Building and Miscellaneous			Total			Net			Unit Cost	
	GOING IN	Unit	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	$	¢
u	Fixed Charges			75			50			53			20			300			498			498			
v	Operating Sup. and Labor			160			160			80			30			50			480			480			
w	Maintenance			5			20			10			10			50			95			95			
x	Miscellaneous			1			30			2			2			5			40			40			
a	Electricity	100 kw hr.	20	60								6	48		14.4	43			151		50.4	151			30
d	Low-Pressure Steam	1,000 lb.				1,644	822											1,644			1,644	822			
e	City Water	1,000 lb.	9,000	14					11,200	17								20,200	822		20,200	31			50
f	Pumped Water	1,000 lb.	450,000	650					53,000	81								503,000	31		503,000	731			015
10a	Strong Liquor						965												731						
10b	High-Pressure Vapor									2,015									965						
10c	Liquid Ammonia												2,258						2,015						
10d	Low-Pressure Vapor																		2,258						
10e	Weak Liquor																								
g	Refrigeration	Tons													1,500	2,368		1,500	2,368						
	Total In			965			2,047			2,258			2,368			2,816			10,454			2,848			
	GOING OUT																								
10a	Strong Liquor			965															965						
10b	High-Pressure Vapor						2,015												2,015						
10c	Liquid Ammonia									2,258									2,258						
10d	Low-Pressure Vapor																								
10e	Weak Liquor																								
G	Refrigeration	Tons										1,500	2,368		1,500	2,816		1,500	5,184		1,500	2,816		1	88
K	Condensate	1,000 lb.				1,644	32											1,644	32		1,644	32			02
	Total Out			965			2,047			2,258			2,368			2,816			10,454			2,848			

The round numbers inserted in the above table are designed solely to illustrate the application. They should not be taken as representative of either good or typical practice.



REFRIGERATING PLANT (ABSORPTION)

POWER Nov. 24, 1931
Cost-Control Number

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AIR-CONDITIONING PLANT

STEAM is the only power service delivered to the factory for building-heating purposes. The quantity can be readily metered and its cost determined by applying the unit rate arrived at by analysis of the boiler plant. Air conditioning and indirect heating require several power services in addition to steam, and it may, therefore, be desirable to analyze the cost of this service. For this purpose an air-conditioning plant has been set up. The main output of this plant is conditioned air. It is not practical to measure this output, consequently no unit cost can be found. As previously suggested, this difficulty can be overcome by estimating the percentage of this service utilized by various departments and dividing the total cost of the air-conditioning service on this basis.

SUBDIVISION 121

Air Washer: Includes air washer, pump for circulating water, pipe and fittings from refrigerating plant to the washer, tempering coils, dampers and control equipment. The fixed charges are based upon the first cost of this equipment. Power service input to this subdivision consists of electricity for operating the pumps, steam for tempering coils and refrigeration for cooling the spray water. The circulation of water from the refrigerating plant to air washer and back has been shown on the chart only as refrigeration service. The output of this subdivision, in addition to conditioned air, may be condensate from tempering coils, or exhaust in case the circulating pumps are steam-engine-driven.

SUBDIVISION 122

Ventilating Fans: The supply and exhaust fans and their drives and duct work are included in this subdivision. The power service inputs are electricity and low-pressure steam, and high-pressure steam in case the fans are steam driven. The fans, of course, receive conditioned air from 121, and fresh and vitiated air, these latter not being shown on the charts. Under some circumstances it would be desirable to show the amount of return air recirculated, because at certain times of the year the heat it contains is of value to the system.

SUBDIVISION 123

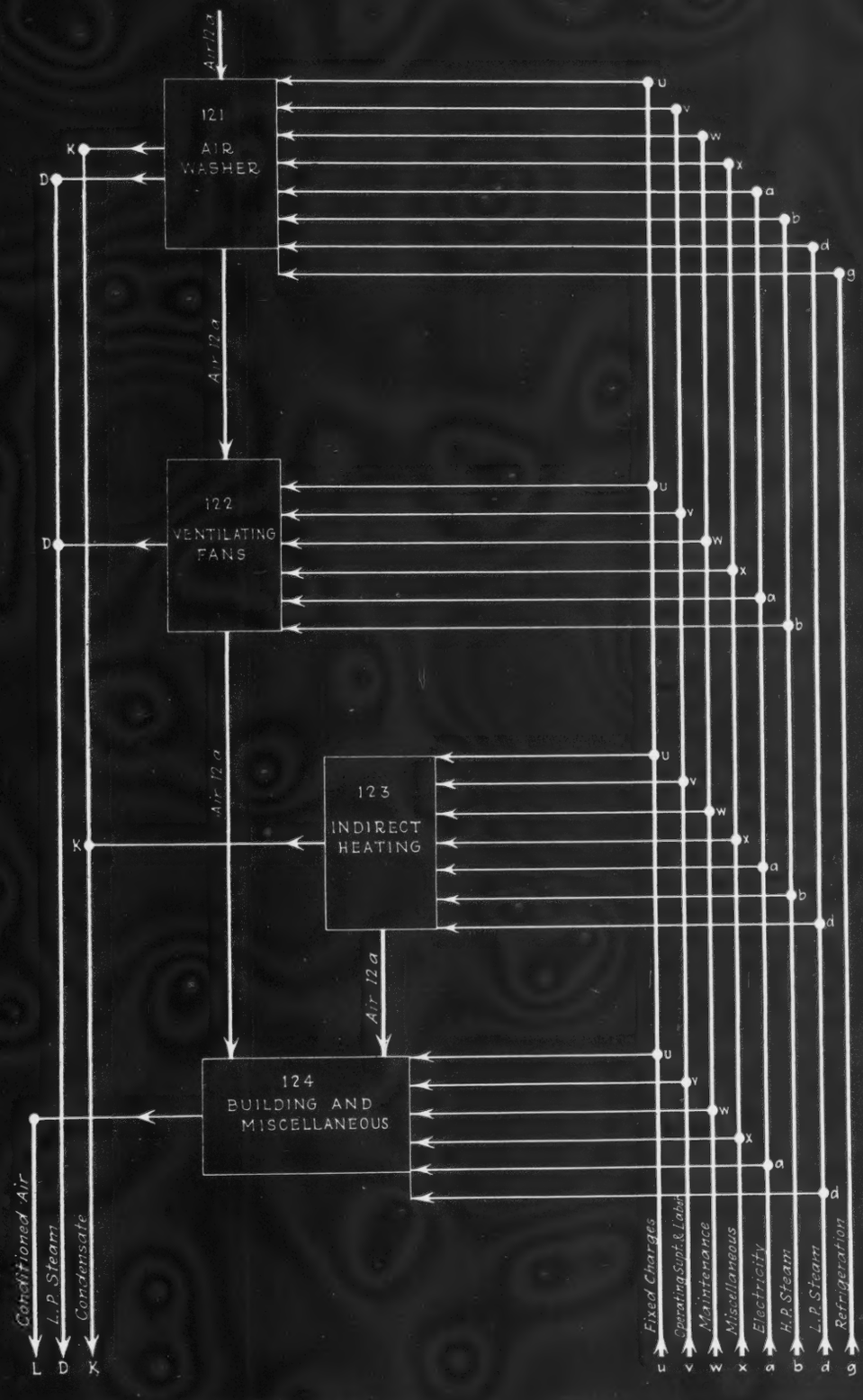
Indirect Heating: Includes the heating coils and associated piping of an indirect heating system. The fans for such a system are included in 122. Where unit heaters are used both the fan and the heating coils would be considered. Electricity for operating the fans of unit heaters is shown as input to this subdivision; otherwise the only power service input is high- or low-pressure steam.

SUBDIVISION 124

Building and Miscellaneous: The outputs of 122 and 124 are run through the building in order that the charges associated with the building or part of the building housing the equipment of this plant may be assessed against air-conditioning service. In the case of unit heaters and space occupied by piping, etc., the building charges presumably would be neglected.

	GOING IN	Unit	121 Air Washing Q	121 Air Washing $	121 Air Washing ¢	122 Fans Q	122 Fans $	122 Fans ¢	123 Indirect Heating Q	123 Indirect Heating $	123 Indirect Heating ¢	124 Building and Miscellaneous Q	124 Building and Miscellaneous $	124 Building and Miscellaneous ¢	Total Q	Total $	Total ¢	Net Q	Net $	Net ¢	Unit Cost $	Unit Cost ¢
u	Fixed Charges			232			16						50			298			298			
v	Operating Sup and Labor			40			20						2			62			62			
w	Maintenance			5												5			5			
x	Miscellaneous			2			3									5			5			
a	Electricity	100 kw-hr.	10.8	22		58	116					.5	1			139			139		2	00
b	High-Pressure Steam	1,000 lb.																				
d	Low-Pressure Steam	1,000 lb.																				
g	Refrigeration	Tons		918												918			918		1	80
12a	Air						1,219						1,374			2,593						
	Total In			1,219			1,374						1,427			4,020			1,427			
	GOING OUT																					
D	Low-Pressure Steam	1,000 lb.																				
L	Conditioned Air	Units										100	1,427			1,427		100	1,427		14	27
K	Condensate	1,000 lb.																				
12a	Air			1,219			1,374									2,593						
	Total Out			1,219			1,374						1,427			4020			1,427			

The round numbers inserted in the above table are designed solely to illustrate its application. They should not be taken as representative of either good or typical practice.



AIR CONDITIONING PLANT

POWER Nov. 24, 1931
Cost-Control Number

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Power Cost Control Applied to an Industrial Plant

THE COST-CONTROL system, master chart and accounting forms explained and described in previous articles of this number are here applied to the power house of the John Doe Manufacturing Company, an industrial plant. This power house supplies the manufacturing processes with electricity, steam at intermediate pressure, hot water and pumped water. The power house contains two 3,000-kw. bleeder turbines and three 6,000-sq.ft. boilers, stoker-fired and equipped with air preheaters. All auxiliaries except a spare feed pump are motor-driven. The pumps for supplying water to the factory, boiler make-up and water heaters obtain their supply from a near-by small river. Two motor-driven pumps are installed, each having a capacity of 200 g.p.m.

To make the application easy to follow, quantity and cost figures have been inserted in the accounting forms and their source will be discussed in detail. These data should not be understood to represent average or current power plant costs and do not apply to any existing plant.

It will be seen that the data in the master chart permit the unit costs of all of the power services delivered to the factory to be determined and are so used in the plant analysis. The more detailed analysis is necessary only when it becomes desirable to find out why the unit cost of a power service appears high.

• • •

MASTER CHART AND ACCOUNTING FORM

THE POWER HOUSE of the John Doe Manufacturing Company has been divided into four plants as shown by the master chart of power services on the facing page. These are the turbine plant, 3; the boiler plant, 4; the water pumping plant, 7, and water-heating plant, 8. The other plants shown on this chart, but not used, have been included merely to keep the form of the original master chart on page 733, but only those service arteries which are used have been shown.

The turbine plant receives services of high-pressure

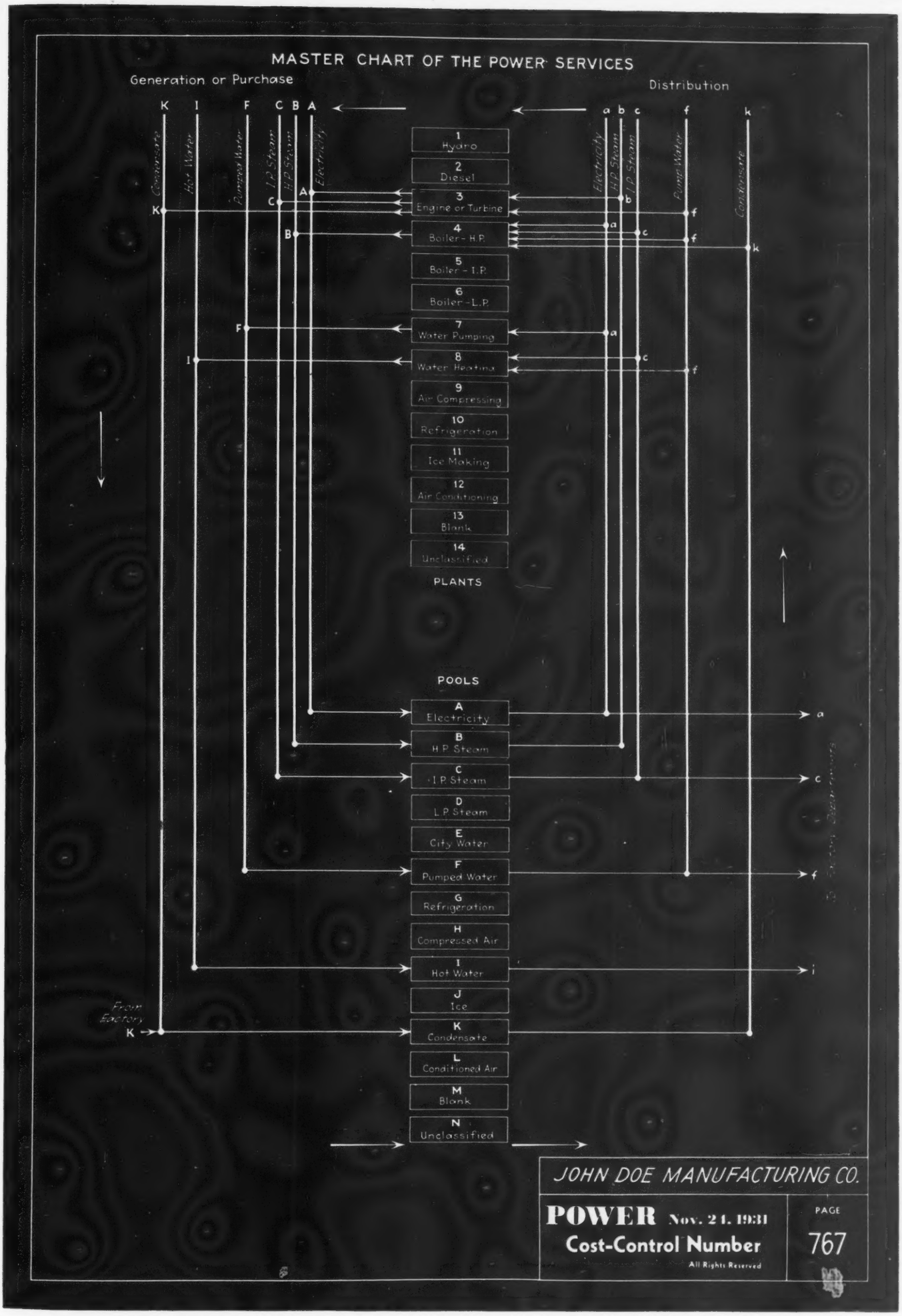
Distribution to Plants

	Plants	Total		Fixed Charges		Operating Sup. and Labor		Maintenance		Miscellaneous		Fuel			Electricity			High-Pressure Steam			Intermed-Press. Steam			Pumped Water			Hot Water			Condensate		
												1,000 lb.			100 kw.-hr.			1,000 lb.			1,000 lb.			1,000 lb.			1,000 lb.			1,000 lb.		
		$	¢	$	¢	$	¢	$	¢	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢	Q	$	¢
3	Turbine	18,538	52	3,139	15	790	32	410	05	335	60							22,800	13,817	90				3,500	45	50						
4	Boiler—H.P	13,817	90	2,597	00	1,140	50	1,010	00	350	00	2,320	5,620	10	275	258	50				2,900	1,552	30	5,500	71	50				17,400	1,218	00
7	Water Pumping	266	80	114	50	89	26	20	10	24	82				193	18	12															
8	Water Heating	822	50	6	00	6	10														1,300	693		9,090	117	40						
	Factory	15,835	10												13,810	12,946	60				3,800	2,034		2,500	32	40	9,090	822	10			
	Total	49,280	82	5,856	65	2,026	18	1,440	15	710	42	2,320	5,620	10	14,102	13,223	22	22,800	13,817	90	8,000	4,279	30	20,590	266	80	9,090	822	10	17,400	1,218	00
	Unit Cost												2	42			94			60			53.5			013			091			07

Generated by Plants

	Plants																															
3	Turbine	14,102	13,223	22							8,000	4,279	30														14,800	1,036	00			
4	Boiler—H.P.				22,800	13,817	90																									
7	Water Pumping													20,590	266	80																
8	Water Heating																9,090	822	10													
	Factory																										2,600	182	00			
	Total	14,102	13,223	22	22,800	13,817	90	8,000	4,279	30	20,590	266	80	9,090	822	10	17,400	1,218	00													
	Unit Cost			94			60			53.5			013			091			07													

The round numbers inserted in the above table are designed solely to illustrate the application. They should not be taken as representative of either good or typical practice.


MASTER CHART OF THE POWER SERVICES
Generation or Purchase
Distribution
K Condensate
I Hot Water
F Pumped Water
C I.P. Steam
B H.P. Steam
A Electricity
a Electricity
b H.P. Steam
c I.P. Steam
f Pump Water
k Condensate
1 Hydro
2 Diesel
3 Engine or Turbine
4 Boiler - H.P.
5 Boiler - I.P.
6 Boiler - L.P.
7 Water Pumping
8 Water Heating
9 Air Compressing
10 Refrigeration
11 Ice Making
12 Air Conditioning
13 Blank
14 Unclassified
PLANTS
POOLS
A Electricity
B H.P. Steam
C I.P. Steam
D L.P. Steam
E City Water
F Pumped Water
G Refrigeration
H Compressed Air
I Hot Water
J Ice
K Condensate
L Conditioned Air
M Blank
N Unclassified
From Factory
K
JOHN DOE MANUFACTURING CO.
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steam and pumped water from the arteries on the right and delivers electricity, intermediate-pressure steam and condensate to the arteries on the left. The boiler plant receives electricity, intermediate-pressure steam, pumped water and condensate, and its output is high-pressure steam.

The water-pumping plant receives only electricity service and its output, pumped water, is delivered to pool *F*. Pumped water and intermediate-pressure steam are the services required by the water-heating plant, and its output, hot water, is used only in the factory. Electricity, intermediate-pressure steam and pumped water are used both in the power house and in the various manufacturing departments.

The accounting form on page 766 is used with the master chart. The horizontal lines represent the various plants as indicated at the left, and the vertical columns represent the power services involved, with the addition of columns for fixed charges, operating superintendence and labor, maintenance, miscellaneous and fuel. In the upper portion of the form are inserted the quantities and costs entering the various plants and in the lower portion are inserted the quantities and costs leaving the plant.

Starting with the upper portion, all items of fixed charges, operating superintendence and labor, maintenance and miscellaneous for the month can be filled in from investment, payroll and supply records. The cost of fuel is readily obtained from the purchasing department. The quantities of electricity, high- and intermediate-pressure steam, pumped water, hot water and condensate can be obtained from meter records and entered on the form in the proper places, but the unit costs of these services is as yet unknown, and the total value cannot be inserted in the form.

It would seem that an impasse had been reached, for the cost of electricity cannot be found until the cost of high-pressure steam is known, but this cannot be determined until the cost of electricity is known. The way out of this dilemma is as indicated in the article "Plant Accounting."

The starting point is the boiler room. It is first necessary to set a value for the condensate returned to the boiler room from the turbine plant and factory. One way of attacking this problem is to consider the unit value of condensate equal to the unit cost of make-up. This has been done, and the unit cost of seven cents applied to the condensate permits filling $1,218 in line 4 under the heading "condensate." This procedure increases the cost of steam to the turbine room and factory, but both of these will receive credit for the condensate returned, and in this way emphasize the economy to be secured by returning as much condensate as is possible.

It is next necessary to make a preliminary estimate of the cost of pumped water. All of the costs involved in this service are known except that of electricity. If a reasonable value be assumed for this a close estimate of the unit cost for the service can be obtained and a value given to the pumped water used in the boiler room. The only unknowns in the cost of steam are now electricity and intermediate-pressure steam, and values for these can be found as follows:

First find the weight of high-pressure steam equivalent to the heat content of the intermediate-pressure steam, and the percentage this weight is of the total steam generated. In this case the equivalent high-pressure steam is 2,635,000 lb. and its percentage of the total is 11.5. Calling this percent R and substituting in the equation $(1 + R + R^2 + R^3)$ the factor 1.129 is obtained. The total boiler room cost, except for the unknown costs of electricity and intermediate-pressure steam, is $12,007.11, which, multiplied by the factor, gives $13,559.41, the cost of steam, including the cost of intermediate-pressure steam. By subtraction the cost of intermediate-pressure steam is found to be $1,552.30, or 53.4c. for 1,000 lb.

	GOING IN	Unit	51 Fuel Preparation Q	51 $	51 ¢	52 Makeup Treatment Q	52 $	52 ¢	53 Feed Water System Q	53 $	53 ¢	54 Fans Q	54 $	54 ¢	55 Ash Handling Q	55 $	55 ¢	56 Finng Equip and Furnaces Q	56 $	56 ¢	57 Boilers Q	57 $	57 ¢	58 Building and Miscellaneous Q	58 $	58 ¢	Total Q	Total $	Total ¢	Net Q	Net $	Net ¢	Unit Cost $	Unit Cost ¢
u	Fixed Charges			92	00		69	00		334	00		77	00		46	00		760	00		1,035	00		184	00		2,597	00		2,597	00		
v	Operating Sup.-and Labor			150	00		50	00		100	00		50	00		100	00		550	00		100	00		40	50		1,140	50		1,140	50		
w	Maintenance			60	00		20	00		130	00		30	00		40	00		600	00		100	00		30	00		1,010	00		1,010	00		
x	Miscellaneous			50	00		10	00		60	00		20	00		20	00		170	00		20	00					350	00		350	00		
y	Fuel	1,000 lb.	2,320	5,620	10													2,320	5,983	40							11,603	50		5,620	10		
a	Electricity	100 kw.-hr.	12	11	30	2	1	88	116	109	25	120	113	00	11	10	32	9	8	20				5	4	55	275	258	50	275	258	50		94
b	High-Pressure Steam	1,000 lb.																						22,800	13,558	85	22,800	13,558	85					
c	Intermed.-Press. Steam	1,000 lb.							2,900	1,552	30																2,900	1,552	30	2,900	1,552	30		536
f	Pumped Water	1,000 lb.				4,500	58	50				600	7	80	200	2	60				200	2	60				5,500	71	50	5,500	71	50		013
k	Condensate	1,000 lb.							17,400	1,218	00																17,400	1,218	00	17,400	1,218	00		07
5a	Feed Water	1,000 lb.							4,500	209	38										24,800	3,712	93					3,922	31					
5b	Fan Service																		297	80								297	80					
5c	Ash Service																		218	92								218	92					
5d	Furnace Heat																					8,588	32					8,588	32					
	Total In			5,983	40		209	38		3,712	93		297	80		218	92		8,588	32		13,558	85		13,817	90		46,387	50		13,817	90		
	GOING OUT																																	
B	High-Pressure Steam	1,000 lb.																			27,800	13,558	85	27,800	13,817	90	27,800	27,376	75	27,800	13,817	90		605
5a	Feed Water	1,000 lb.				4,500	209	38	24,800	3,712	93																	3,922	31					
5b	Fan Service												297	80														297	80					
5c	Ash Service															218	92											218	92					
5d	Furnace Heat																		8,588	32								8,588	32					
y	Fuel	1,000 lb.	2,320	5,983	40																							5,983	40					
	Total Out			5,983	40		209	38		3,712	93		297	80		218	92		8,588	32		13,558	85		13,817	90		46,387	50		13,817	90		

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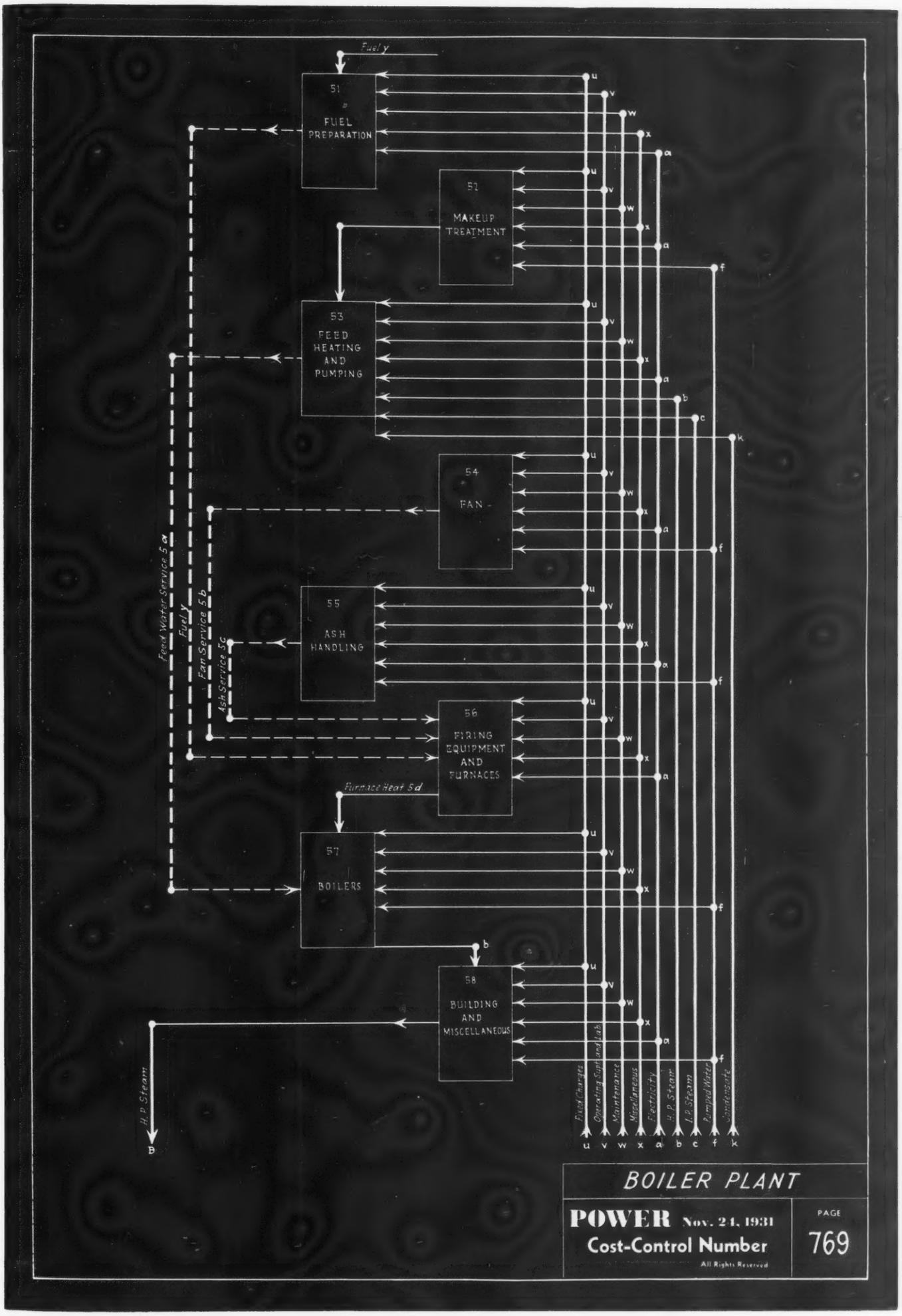

BOILER PLANT

POWER Nov. 24, 1931
Cost-Control Number
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The cost of this service to the boiler plant, water heating plant and the factory can now be entered in the accounting form.

The next step is to determine what per cent of net electricity delivered by the turbine plant is returned to the boiler room for auxiliary use. Since the net output from the turbine plant is 1,410,200 kw.-hr. and the boiler room uses 27,500 kw.-hr. this figure is 1.95 per cent. The cost in the turbine room, plus $13,559.41, the cost of steam without the cost of auxiliary power, totals $18,279.50. Crediting the turbine room $4,279.30 for the intermediate-pressure steam delivered and $1,036 for condensate, the cost of electricity excepting that used for boiler auxiliaries is $12,964.50. This sum multiplied by $(1 + .0195 + .0195^2)$ gives the total cost of electricity as $13,215.75, and dividing by 1,410,200 kw.-hr. the unit cost becomes 94 mills per kilowatt-hour. Using this unit cost, the rest of the cost items in the table can be inserted. It will be noted that the final corrected cost for electricity is only $7.47 more than the calculated cost, thus giving a very close check on the method employed.

• • •

COST ANALYSIS OF PLANTS

IN THE power house used in this example the water-pumping and water-heating plants are so small that it is not considered worth while making any further analysis of them. It would probably be desirable, however, to make a detailed analysis at various times of the boiler and turbine plants. The plant charts and accounting forms on this and the following pages present a means for analyzing the turbine and boiler room plants. It should be recognized, however, that this detailed analysis is not necessary for each accounting period. It need only be done when the unit cost derived on the master accounting form indicates the service from one of these plants to be higher than good practice would indicate.

The first chart and form show the boiler plant separated into eight subdivisions. These subdivisions permit the cost of fuel preparation, make-up treatment, feed-water systems, fans, ash handling, firing equipment and furnaces, and boilers, to be determined. It should be noted that all of the items in the net columns of both the boiler and turbine plant forms agree with the respective cost items on the master accounting form.

The second chart and accounting form show the turbine plant separated into the five following subdivisions: condenser and auxiliaries, turbine-generator, switchboard and bus structure, miscellaneous auxiliaries and building and miscellaneous.

Boiler Plant

SUBDIVISION 51

Fuel Preparation: As shown by the chart, the costs entering this subdivision are fixed, operating superintendence and labor, maintenance and miscellaneous charges, together with the cost of fuel and electricity service. The equipment included in this subdivision is the machinery necessary to crush the coal and convey it to the boiler house bunkers. Fixed charges on the investment in boiler house bunkers, and storage facilities, are included in this item.

SUBDIVISION 52

Make-Up Treatment: Make-up is obtained from the water pumping plant and treated with zeolite. The cost of make-up treatment includes fixed charges, labor, maintenance and miscellaneous items, together with the cost of electricity and pumped water. The miscellaneous item includes the cost of salt for regenerating the zeolite.

SUBDIVISION 53

Feed-Water Systems: Feed-water heaters and feed pumps, together with all of the piping carrying water from the condensate pump to the boilers, are included in this system, and as part of the boiler plant, although much of this equipment is actually located in the turbine room. This division is charged with the cost of condensate, intermediate-pressure steam, make-up water and electricity for pumping. A steam-driven pump is included in the fixed charges, but was not used during this accounting period, thus no high-pressure steam has been charged against this subdivision.

SUBDIVISION 54

Fans: Induced and forced draft fans, together with all of the duct work and stacks, are considered in determining the fixed charges assessed against this subdivision. In addition to the cost of labor, maintenance and miscellaneous items, the cost of electricity for operating the fan motor and pumped water for bearing cooling is charged for.

SUBDIVISION 55

Ash Handling: Includes ash hoppers, nozzles, sluice and sluicing water pumps and contingent piping. This subdivision is also charged with the electricity for operating the ash-sluicing pump and with pumped water for spraying the ashes as they drop from the furnace.

SUBDIVISION 56

Firing Equipment and Furnaces: Charged against this subdivision is the cost of fuel preparation, fan service and ash handling. The equipment upon which fixed charges are based includes stokers, clinker grinders, boiler room instruments and boiler settings. This last item is included here because furnace maintenance is closely connected with combustion. The output from this division has been called furnace heat, and is charged directly to the boilers.

SUBDIVISION 57

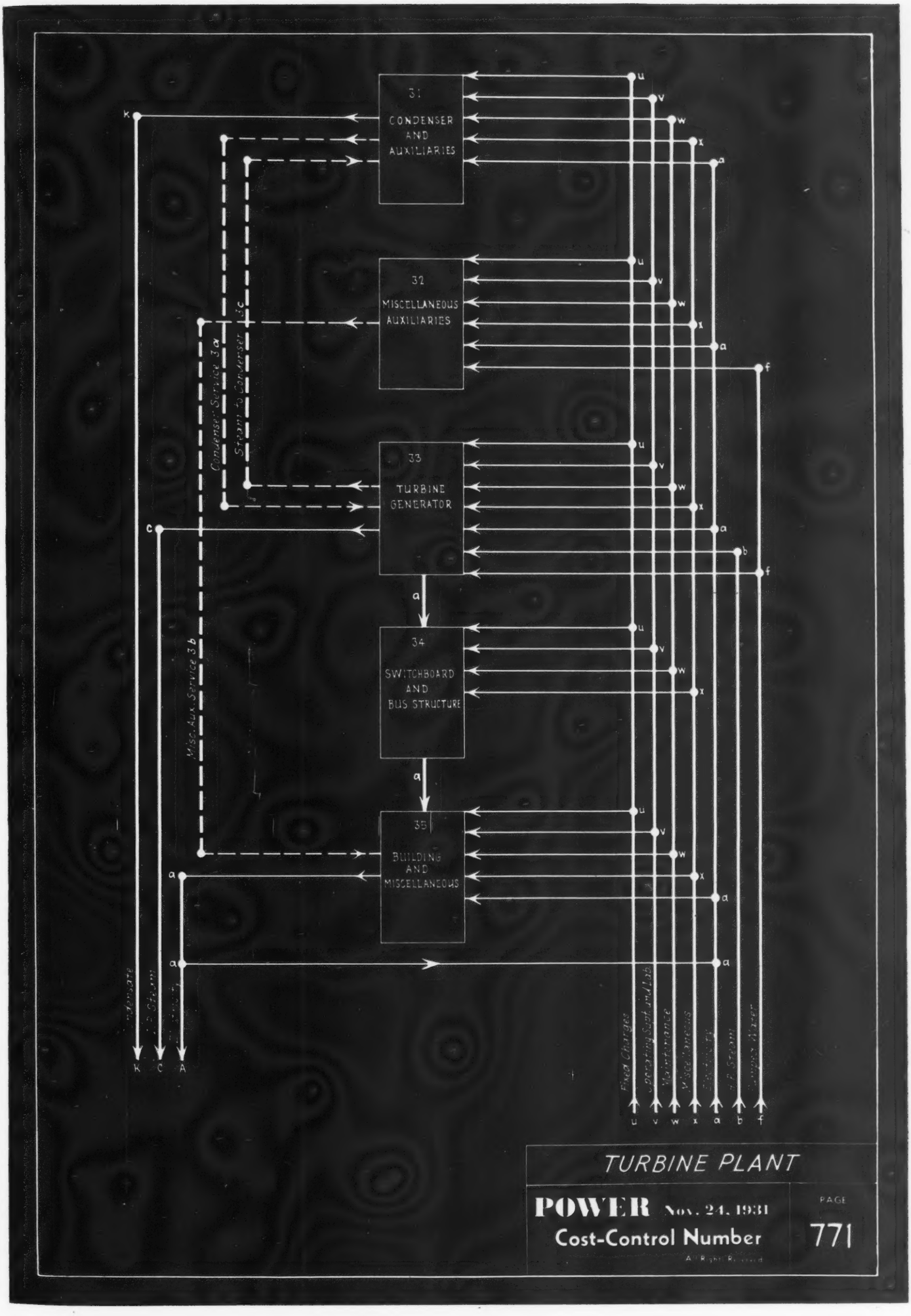
Boilers: Includes the boiler, air preheater, soot blowing equipment, blowdown piping, steam piping to the turbine plant, and other boiler accessories. In addition to the cost of furnace heat this subdivision is charged with the cost of the feed-water system.

The amount of pumped water used in the boiler subdivision, as well as that used in 54 and 55, will generally have to be estimated, as a meter for each of these subdivisions is hardly worth while. The most that can be expected is a meter measuring the make-up water and a second meter measuring the total pumped water to the boiler plant.

SUBDIVISION 58

Building and Miscellaneous: As has been indicated in the previous chart, the output from the plant is run through the building in order that it will pick up the various charges associated with the building.

The values inserted under the "total" column have no meaning whatsoever, it being merely space provided to place down the sum of the horizontal lines. The difference between the item totals on the ingoing side of the form and similar items in the outgoing portion



TURBINE PLANT

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of the form yields the values in the "net" column, and represents the cost and quantities of the various power services involved.

Turbine Plant

SUBDIVISION 31

Condenser and Auxiliaries: Includes condenser, circulating-water pumps, air pumps, condensate pump and piping up to the discharge of the condensate pump. In addition to fixed, operating superintendence and labor, maintenance and miscellaneous charges, this subdivision receives electricity for operating motor drives and steam exhaust from the turbines. The value of the latter is considered to equal the value of condensate. Electricity is charged for at the rate determined in the master accounting form. The value of the condensate output has been previously discussed and is credited to the condenser. The remainder of the cost condenser service is charged to the turbine generator through line 3a.

SUBDIVISION 32

Miscellaneous Auxiliaries: In this example an air compressor, separate exciter, and turbine room crane together with all associated piping and electrical equipment, have been considered in calculating fixed charges. Electricity is used for motor drives and pumped water for cooling in the air compressor. The output, miscellaneous auxiliary service, is most conveniently charged into 35.

SUBDIVISION 33

Turbine-Generator: The generating units are each of 3,000 kw. capacity and bleed steam at about 75 lb. pressure to the intermediate-pressure steam pool *C*. During the accounting period the unit receives 22,880,000 lb. of high-pressure steam, of which 8,000,000 lb. is bled and 14,800,000 lb. is exhausted to and charged against the condenser. In calculating fixed charges the first cost of the lubricating system and steam piping have been included. This subdivision is also charged with the cost of condenser operation determined under 31.

SUBDIVISION 34

Switchboard and Bus Structure: The input to this subdivision is the output of 33 together with fixed, operating superintendence and labor, maintenance and miscellaneous charges. Included in this subdivision are the main unit switches and generator leads, switchboard, instruments and bus structure.

SUBDIVISION 35

Building and Miscellaneous: This subdivision comprises the building that houses the turbine plant. Input assessed against it is fixed, operating superintendence and labor, maintenance and miscellaneous charges, together with electricity for lighting. The output from 35, as in the boiler plant, is run through the building in order that the building costs may be assessed against the electricity output. Electricity for auxiliary use within the turbine plant is taken from the output artery *A* before it leaves the plant, its final output being net kilowatt-hours, condensate and intermediate-pressure steam.

	GOING IN	Unit	31 Condenser and Auxiliaries Q	$	¢	32 Miscellaneous Auxiliaries Q	$	¢	33 Turbine or Engine Unit Q	$	¢	34 Switch Board and Bus Structure Q	$	¢	35 Building and Miscellaneous Q	$	¢	Total Q	$	¢	Net Q	$	¢	Unit Cost $	¢
u	Fixed Charges			345	00		58	00		1,828	00		655	00		253	15		3,139	15		3,139	15		
v	Operating Sup. and Labor			150	32		60	00		420	00		130	00		30	00		790	32		790	32		
w	Maintenance			50	05		15	00		200	00		140	00		5	00		410	05		410	05		
x	Miscellaneous			30	00		20	30		150	20		130	10		5	00		335	60		335	60		
a	Electricity	100kw.-hr.	271	254	74	21.4	20	12				14,400	12,149	83	14,406	13,210	57	29018.4	25635	26					
b	High-Pressure Steam	1,000 lb.							22,800	13,817	90								13,817	90	22,800	13,817	90	.605	
f	Pumped Water	1,000 lb.				1,000	13	00	2,500	32	50							3,500	45	50	3,500	45	50	.013	
3a	Condenser Service									830	11								830	11					
3b	Misc. Aux. Service									186	42								186	42					
3c	Steam to Condenser	1,000 lb.		1,036	00														1,036	00					
	Total In			1,866	11		186	42		17,465	13		13,204	93		13,503	72		46,226	31		18,538	52		
	GOING OUT																								
A	Electricity	100kw.-hr.							14,400	12,149	83	14,400	13,204	93	14,400	13,503	72	43,200	38,858	48	14011.4	13,223	22	.94	
C	Intermed-Press. Steam	1,000 lb.							8,000	4,279	30							8,000	4,279	30	8,000	4,279	30	.536	
3b	Misc. Aux. Service						186	42											186	42					
K	Condensate	1,000 lb.	14,800	1,036	00													14,800	1,036	00	14,800	1,036	00	.07	
3a	Condenser Service			830	11														830	11					
3c	Steam to Condenser	1,000 lb.							14,800	1,036	00							14,800	1,036	00					
	Total Out			1,866	11		186	42		17,465	13		13,204	93		13,503	72		46,226	31		18,538	52		

The round numbers inserted in the above table are designed solely to illustrate its application. They should not be taken as representative of either good or typical practice.

NEWS of the FIELD

Eleven Sessions Devoted to Power Subjects at A. S. M. E. Annual Meeting, Nov. 30 to Dec. 4

ELEVEN of the 26 technical sessions of the American Society of Mechanical Engineers' annual meeting in New York City, Nov. 30 to Dec. 4, will be devoted to subjects in the power field. Industrial power, fuels, coal handling, central station power, boiler feed water, steam tables, hydraulics, fluid meters, oil and gas power, and lubrication are among the topics to be discussed.

Other sessions will emphasize the economic and social aspects of engineering, dealing with such subjects as business stabilization, engineering economics, management research, earnings of engineers, accident prevention and psychology.

For the first time in several years the Towne and Thurston lectures will both be given at the annual meeting. The Towne lecture, which deals with the relationship between economics and engineering, will be delivered Tuesday afternoon by Dean W. B. Donham, of the Graduate School of Business Administration at Harvard University. The Thurston lecture will be given on Thursday afternoon by Dr. Edward L. Thorndike, professor of education at Teachers College, Columbia University, on the subject of "Psychology and Engineering."

At the annual banquet Wednesday evening honorary membership will be conferred on Dr. Calvin W. Rice in recognition of his 25 years' service as secretary of the society. Honorary membership will also be conferred on Dr. Palmer C. Ricketts, president of Rensselaer Polytechnic Institute, for his important work in engineering education. The award will be made to Dr. Ricketts on President's Night, Dec. 1.

Among the other features of the general program will be the report and recommendations of the Committee on the Economic Status of the Engineer; an address on accident prevention by Frances Perkins, Industrial Commissioner of New York; and the engineers' art exhibit.

The program of papers related to the power field is as follows:

MONDAY, NOV. 30

"Rustless Steel Conveyors — Their Availability, Application and Use," N. W. Elmer; "Application and Design of the Floating Drive for Conveyors," N. H. Preble; "Progress Report of Materials Handling Division," F. D. Campbell; "A Study of Primary Metering Elements in 3-in. Pipe," S. R. Beitler, Paul Bucher and T. C. Barnes; "Flow of Steam Through Square-Edge Orifices in 4-in. Line," W. W. Frymoyer and A. Herschel.

TUESDAY, DEC. 1

"Ford Motor Company's 1,200-lb. Steam-Plant Installation," A. R. Smith and H. B. Hanson; "Characteristics of a High-Pressure Series Steam Generator," A. A. Potter, H. L. Solberg and G. A. Hawkins; "Once-Through Series Boiler for 1,500 to 5,000 Lb. Pressures," H. J. Kerr; "Report of Power Division"; "Optimum Conditions in Journal Bearings," Albert Kingsbury; "Pressure Distribution in the Oil Films of Journal Bearings," S. A. and T. R. McKee; "Oil-Film Pressures in an End-Lubricated Sleeve Bearing," L. J. Bradford.

WEDNESDAY, DEC. 2

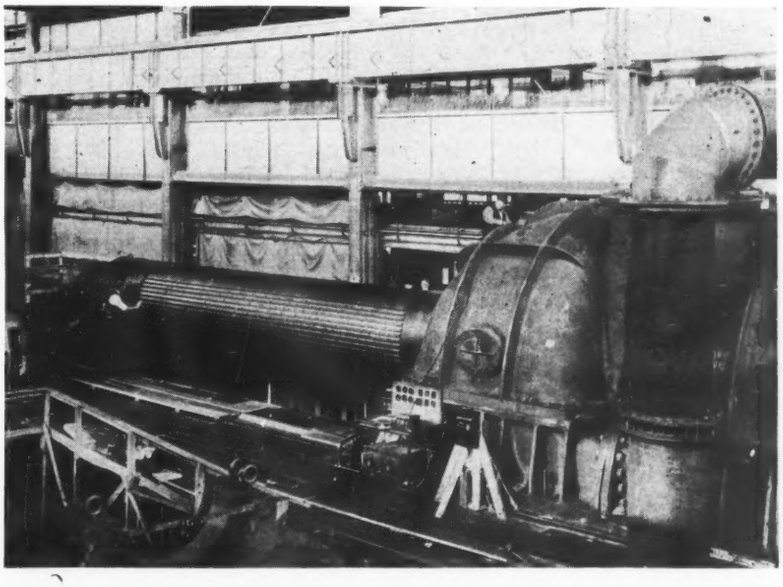
"Fluxing of Ashes and Slags as Related to the Slagging-Type Furnace," P. Nicholls and W. T. Reid; "Report of Fuels Division"; "Hydraulic Butterfly Valves," R. L. Mahon; "Piezometer Investigation," C. M. Allen and L. J. Hooper; "Progress Report of Hydraulic Division"; "Progress Reports on Steam Tables," L. B. Smith, F. G. Keyes, N. S. Osborne and H. N. Davis; "Leakage Loss and Axial Thurst in Centrifugal Pumps," A. J. Stepanoff; "Turbulence in Centrifugal Pumps," J. W. Macmeeken; "Economic Life of Equipment," H. O. Vorlander and F. E. Raymond.

THURSDAY, DEC. 3

"Performance of Modern Steam-Generating Units," C. F. Hirshfeld and G. U. Moran; "Solubility of Calcium Salts in Boiler Water," F. G. Straub; "Influence of Inlet Boxes on the Performance of Induced-Draft Fans," L. S. Marks and E. A. Winzenburger; "Small Marine-Diesel Installations," L. B. Jackson; "United States Navy Diesel-Engine Requirements," Commander Holbrook Gibson; "Determination of Carbonate, Hydroxide and Phosphate in Boiler Waters—Progress Report of Subcommittee No. 8," W. C. Schroeder and C. H. Fellows; "Foaming and Priming of Boiler Water," C. W. Foulk; "The SO_4/CO_3 Ratio for the Prevention of Sulphate Boiler Scale," E. P. Partridge, W. C. Schroeder and R. C. Adams, Jr.

▼ ▼ ▼

TEST 160,000-KW. ROTATING FIELD



Testing for dynamic balance the revolving field of one of the two 160,000-kw. turbine-generators for the Hudson Avenue station of the Brooklyn Edison Company at the Schenectady plant of the General Electric Company. This is the largest 1,800-r.p.m. revolving field ever built both as to size and capacity

Pipe Welding and Tests Featured at Chicago Convention of International Acetylene Assn.

Welding tests about to be demonstrated at the I.A.A. convention

FROM Nov. 11 to 13, inclusive, the International Acetylene Association held its 32nd annual convention at the Congress Hotel, Chicago. A total registration of 500 indicated the interest that was taken in a progressive program featuring many of the later phases of oxy-acetylene welding and cutting, welding education, and a spectacular demonstration of welding tests, made as a part of an evening session devoted to welds, weld tests and the welder. Dramatized by John J. Crowe, of the Air Reduction Laboratories, and Dr. A. B. Kinzel and W. B. Miller, engineers of the Union Carbide & Carbon Research Laboratories, these tests were made on the stage before an audience exceeding 1,000 with every type of known testing equipment.

Other sessions of the convention were devoted to transportation including air, rail and motor vehicles; welded piping, and welding in the chemical industry. In the session last named gas welding opportunities under the revised A.S.M.E. boiler code were outlined by C. W. Obert.

In a paper dealing with the management of large piping installations, G. K. Deatherage showed how welded piping systems could be installed with lower erection labor costs than screwed or flanged lines. Shop fabrication of welded piping systems, resulting in delivery to the job of all the material with nothing but assembly remaining to be done, has made this possible.

Of more direct interest to the power plant field was a paper by S. Hirschberg of the Crane Company on recent developments in piping and pipe fittings for welded construction. A large assortment of fittings especially designed for welding were considered, and attention given to the three factors; strength, compactness and pressure drop due to friction, in the design of elbows and tees. Other items given brief consideration were provisions for expansion and contraction in welded piping installations; the relative flexibility of the square bend made of seamless elbows and straight pipe, and the conventional expansion loop; development work now under way to build valves more suitable for welding; welded headers, and shop fabrication.

F. W. Martin of Sargent & Lundy, Inc., presented some interesting data on specifications for welded piping for high-temperature and high-pressure steam service, made up principally of abstracts from many welding specifications used by different concerns, which had come to the author's attention during the past year, and embodying his ideas as to some of the points that must be covered in such a specification.

Officers elected for the coming year are: President, W. C. Keeley, Jr., National Carbide Corporation, New York City; vice-president, E. J. Hayden, Linde Air Products Company, Chicago; secretary, H. F. Reinhard, J. B. Colt Company, New York City; treasurer, W. E. Cotter, Union Carbon & Carbide Company, New York City.

Utica G.&E. Rebuilds Trenton Falls Station

A PROGRAM of reconditioning and reconstruction has been carried out by the Utica Gas & Electric Company on its Trenton Falls hydro-electric station, resulting in increased capacity and thorough modernization of the plant.

Four 1,800-hp. units, installed in 1900, were overhauled for the first time, with a resultant increase in capacity of approximately 20 per cent. This involved welding up the bronze runners and distributors, and included machining and refinishing the parts.

In addition 2,900 ft. of 30-year-old 7-ft. wood-stave pipe line was torn out and replaced with steel-plate pipe having arc-welded longitudinal joints and riveted circumferential joints, the pipe being supported on steel saddles.

New racks were installed to replace those in service since 1900, and racks were added to cover four more pipes not so equipped. Individual gate-operating motors and remote control from the power house were also installed, together with a crossover between the 7-ft. and 12-ft. pipe lines in order to enable the two lines to work in parallel and thus better the operating head on the three 10,000-hp. units, which were installed in 1918.

New Unit Nearly Ready at Holyoke (Mass.) Plant

UNIT No. 8, latest addition to the Connecticut River plant of the Holyoke Water Power Company at Holyoke, Mass., is rapidly nearing completion and is scheduled for operation on Dec. 1. The new unit comprises a 6,000-hp. water wheel of the propeller type, operating under a head of 30 ft. at 128 r.p.m. The generator has a rating of 5,000 kva., 2,300 volts, 60 cycles, and it will operate at a power factor of 0.8. Installation of the unit was started on Apr. 1 of this year and included the construction of new penstocks of the double-square concrete type, 120 ft. long and 13 ft. in diameter.

P. G. & E. to Build 30,000-Hp. Plant at Brush Creek, Calif.

FOLLOWING NEGOTIATION between directors of the Sacramento (Calif.) Municipal Utility District and officials of the Pacific Gas & Electric Company, an agreement has been reached whereby that company will lease the water to be impounded at the Silver Creek dam and use it for the generation of power. Under the agreement the Municipal Utility District will bond itself to build conduits and tunnels to bring water to the power house which the company will build at the mouth of Brush Creek.

Plans are now being drawn up for an election to be held at a date not yet named at which the voters will be asked to approve a bond issue of $10,800,000 for the construction of the water project and one for $1,800,000 for the construction of the Brush Creek conduit and tunnels, a total of $12,600,000. The Pacific Gas & Electric Company will spend approximately $2,500,000 on the Brush Creek power house, which will have a capacity of between 26,000 and 30,000 horsepower.

Call Engineering Board to Settle St. Lawrence Plan

A TREATY by Christmas appears to be the Administration's ambition in its negotiations with the Canadian Government on the St. Lawernce waterway. Secretary of State Stimson announced following a conference Nov. 14 with W. D. Herridge, the Canadian Minister, that arrangements have been made for assembling immediately the joint engineering board to reach agreement on the plan for the development in the International Rapids section. That the American engineers will agree to the two-stage development urged by the Canadian engineers in 1926 is a foregone conclusion.

Last week's exchange of views was confined to the allocation of engineering works in the international section and division of the costs of such work between the two countries. Consideration was given to the work planned in the national sections of the project to the extent that these are essential as links in the development of navigation from the head of the lakes to tidewater but Secretary Stimson explained that otherwise the development of the national sections is regarded as a domestic matter.

Announcement that the representatives of both countries propose to keep in touch with the provincial and state authorities in considering the power features of the development is regarded as a sop to the State of New York. Any doubt that the Administration will permit the claims advanced by the state to the hydro-electric by-product of the navigation project to interfere with drafting of the treaty was removed when Secretary Stimson talked to officials of the State Power Authority on Oct. 28.

Fuels Cost U. S. Industries Nearly $1,500,000,000 a Year

AMERICAN MANUFACTURING INDUSTRIES spent $1,498,228,952 for fuels of all kinds in 1929, according to a special fuel report of the Census of Manufactures made public Nov. 16. Of this total, $43,543,316 was spent for 9,281,416 tons of anthracite, $754,509,376 for 214,024,754 tons of bituminous coal, and $243,649,015 for 52,391,839 tons of coke.

Expenditures for fuel oils totaled $212,639,372 for 6,583,198,995 gal.; for gasoline and kerosene, $7,556,341 for 48,473,195 gal. The cost of natural gas amounted to $69,869,067 for 388,902,064,000 cu.ft.; and of manufactured gas, to $81,078,049 for 512,831,454,000 cu.ft. The outlay for all other fuels was $85,384,416.

In addition, manufacturing industries spent, in 1929, $475,634,377 for 36,393,833,046 kw.-hr. of electric energy generated outside their own plants, principally in public-service power plants. A large part of this energy was generated by the consumption of fuel in public-service power plants, but neither the quantity nor the cost of this fuel is covered by the foregoing figures.

Comparing 1929 with 1919, the figures show the following increases and decreases: Anthracite, a decrease from 14,334,402 to 9,281,416 tons; bituminous coal, an increase from 203,463,622 to 214,024,754 tons; coke, an increase from 42,595,019 to 52,391,839 tons; fuel oils, an increase from 3,766,779,366 to 6,583,198,995 gal.; gas (total, both natural and manufactured), an increase from 341,951,022 to 913,831,994,000 cu.ft. (The 1919 report does not show separately the consumption of manufactured gas and of natural gas.)

A report in printed form giving detailed statistics on consumption of fuel by industries, states, and counties will be issued by the Bureau of the Census in the near future.

New Power Equipment Ordered for West Point

EQUIPMENT for a complete new power plant for the United States Military Academy at West Point, N. Y., has been ordered from the Westinghouse Electric & Manufacturing Company. This equipment includes two 1,000-kw., non-condensing turbine-generators and a switchboard for the control of these machines and for the distribution of the power generated.

The plant now in service at the Academy generates direct-current, a small portion of which is converted to alternating-current. The apparatus ordered for the new plant will provide a changeover to alternating-current, except for a small portion of direct-current that is absolutely essential.

A feature of the new power plant will be the inexpensive generation of by-product power from steam used for building heating.

COMING CONVENTIONS

American Society of Mechanical Engineers. Annual meeting in New York City, Nov. 30-Dec. 4. Secretary, Calvin W. Rice, 33 West 39th St., New York City.

American Institute of Electrical Engineers. Annual winter convention in New York City, Jan. 25-29, 1932. Secretary, F. L. Hutchinson, 33 West 39th St., New York.

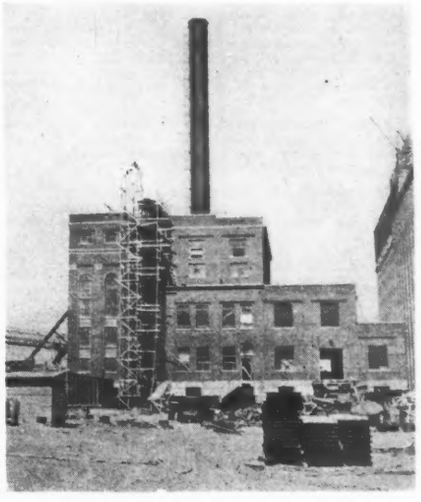
American Society of Refrigerating Engineers. Joint meeting with the A.S.H.V.E. and annual convention at the Hotel Cleveland, Cleveland, Ohio, Jan. 26-29, 1932. Secretary, David L. Fiske, 37 West 39th St., New York City.

American Water Works Association. Annual convention at the Hotel Peabody, Memphis, Tenn., May 2-6, 1932. Secretary, Beekman C. Little, 29 West 39th St., New York City.

Seventh Annual Conference on Welding, to be held by the Engineering Extension Department of Purdue University at Lafayette, Ind., Dec. 10-11. Professor in charge, W. A. Knapp, Engineering Extension Department, Purdue University, Lafayette, Ind.

Steam Plant Built to Serve Grain Elevator in Far North

PUBLIC ATTENTION has been centered recently on the developments at Churchill, Manitoba, where a modern port with grain storage facilities has been constructed on the shores of Hudson Bay. Since the big grain elevator is situated so far from any electrical power, it was necessary to build a steam plant on the site to operate the elevator and supply power for the town site.



Power Plant on Hudson Bay

The power house has a capacity of 3,600 kw. Steam is supplied by one 3,000-sq.ft. and two 6,000-sq.ft. boilers, burning crushed coal on automatic stokers with forced and induced draft. Two turbine-generators rated at 150 kw. and one at 600 kw. supply electrical energy at 60 cycles, 550 volts.

In the turbine room there are also two 850-kva. synchronous condensers. As the connected load of approximately 6,000 hp. is all in induction motors, these condensers were required to correct the power factor of the load.

The main control board handles the three generators, the two condensers and the battery-charging set. There is also a totalizing metering panel and a regulator panel. Behind this panel is a single station bus to which all units may be connected by disconnects and breakers. The bus carries along overhead to a nineteen-panel board which has control of the various elevator feeders. From the feeder breakers the lines are carried to various parts of the elevator.

European Turbine Practice Described in Nov. 17 Number

THE ARTICLE entitled "Recent Developments in European Turbine Practice," by Prof.-Dr. Wewerka, was inadvertently listed on the contents page of *Power*, Nov. 10, as appearing in that number. This article was published in the Nov. 17 number on page 719.

NEW PLANT CONSTRUCTION

COMPILED BY THE MCGRAW-HILL BUSINESS NEWS DEPARTMENT, WHICH IS PREPARED TO FURNISH A MORE COMPLETE DAILY SERVICE TO THOSE WHO WISH IT

Calif., Los Angeles—Dept. of Water Power, City Hall, awarded contract for 17,000 kva. vertical main unit generator to Allis Chalmers Mfg. Co., 117 Rowan Bldg., three 5,833 kva. single ph. step-up outdoor type transformers to General Electric Co., 5201 Santa Fe Ave., and one vertical turbine prime mower to Newport News Shipbuilding & Dry Dock Co., 90 Broad St., New York, N. Y., in connection with San Francisquito power plant No. 2. Estimated total cost $218,927.

Conn., Farmington—City is having plans prepared for construction of a sewage disposal plant including small pumping station, etc. Estimated cost $25,000.

Illinois—U. S. Government War Dept., 333 North Michigan Ave., Chicago, awarded contract for construction of three control houses at Locks, Starved Rock, Marseilles and Lockport to Schmidt Bros. Construction Co., 22 East Huron St., Chicago. $37,825.

Ind., Fort Wayne — City awarded contract for installation of two ash hoppers, Div. 3 to Allen-Sherman-Hoff Co., Lewis Bldg., Philadelphia, Pa., forced draft fans, cinder collectors, steel stacks Divs. 4 and 5 to Western Gas Construction Co., 2001 East Pontiac St., Fort Wayne, two electric driven and one steam driven boiler feed pumps and six other centrifugal pumps with motors, Divs. 6 and 7 to Ingersoll-Rand Co., 11 Broadway, New York, N. Y., six feed water heaters and one boiler water reconditioning system, Divs. 8 and 9 to Cochrane Corp., 17 Bl. and Allegheny Ave., Philadelphia, Pa., exciter and motor control Div. 10 to General Electric Co., 1635 Broadway, Fort Wayne, in connection with light and power plant. Total cost, $70,023.

Kan., Newton—City plans election Nov. 24 to vote $300,000 bonds for a gas distribution plant.

La., Monroe—Morehouse Ice Co., Inc., 1000 Ouachita National Bank Bldg., will soon receive bids for construction of a 1 and 2 story ice plant.

Mass., Norwood—Town, C. A. Bingham, Mgr., preparing preliminary plans for construction of a 2 story recreation building including boiler plant, etc. McLaughlin & Burr, 88 Tremont St., are architects.

Mich., Lansing—City voted $500,000 bonds for construction of a sewage treatment plant including pumping station, etc. S. C. Jacka, City Hall, is engineer.

Mich., Negaunee—City prepared plans for extension to waterworks system including filter plant, pumping units, etc. Estimated cost $89,800. Pearse, Greeley & Hansen, 6 North Michigan Ave., Chicago, Ill., are engineers.

Minn., Moose Lake—City awarded contract for construction of electric light and power plant including generating equipment and distribution system to J. A. Sandahl, Moose Lake. $28,000.

Miss., Biloxi—U. S. Veterans Administration, Construction Service, 764 Arlington Bldg., Washington, D. C., will receive bids until December 8 for a group of buildings including refrigeration and ice making plant at Soldiers' Home Naval Reserve Park. Estimated cost $800,000.

Miss., Columbus—City plans construction of a light plant. Estimated cost $150,000. Burns & McDonnell Engineering Co., 400 Interstate Bldg., Kansas City, Mo., is engineer.

Mo., Dixon—City plans election in spring to vote $40,000 bonds for waterworks improvements including deep well and pumps, distribution lines, tank on tower, etc. Western Engineering Co., Olive and Robberson Sts., Springfield, is engineer.

Mo., Lees Summit—City plans election in January (postponed date from November 10), to vote $50,000 bonds for construction of municipal light and power plant and distribution system. W. B. Rollins & Co., 339 Railway Exchange Bldg., Kansas City, are engineers.

Mo., St. Louis — Artificial Ice Co., 3715 Easton Ave., awarded contract for a 2 story addition to ice plant to A. H. Stiel, 813 Chestnut St.

Mo., St. Louis—Kroger Grocery & Baking Co., A. S. Grogg, General Mgr., 3816 Shaw Ave., St. Louis, and 35 East 7th St., Cincinnati, O., will receive bids about December 10 for a 4 story, 85 x 130 ft. bakery and garage building, boiler room, etc., at 1311 South 39th St. Estimated cost $750,000. Emil H. Niemann, 3816 Shaw Ave., is architect.

Mo., Springfield—Bureau of Federal Prisons, c/o S. Bates, Supervisor, will soon award contract for construction of a group of buildings, including 95 x 28 ft. main building, 128 x 296 ft. acute building, 128 x 296 ft. continued treatment building, 50 x 227 ft. storehouse, 44 x 68 ft. boiler house, etc., for Hospital for Defective Delinquents here. J. A. Wetmore, U. S. Treasury Dept., Washington, D. C., is acting supervising architect. Joannes & Marlow, 420 Lexington Ave., New York, N. Y., are associate architects.

N. J., Chatham — Jersey Central Power & Light Co., awarded contract for transformers and overhead equipment for power plant to Westinghouse Electric & Mfg. Co., 150 Broadway, New York, N. Y.

N. J., Scotch Plains—Board of Chosen Freeholders, Court House, will soon award contract for addition and alterations to power and garage building for Sanitorium here. Estimated cost $40,000. Oakley & Son, 1259 Clinton Pl., Elizabeth, are architects.

New York—North New York Utilities Co., Inc., Light & Power Bldg., Watertown, plans extensions to electric light plant in Lewis County.

N. Y., Brooklyn—Kings County Lighting Co., 6740 4th Ave., plans additions and extensions to gas plant at New Utrecht Ave. and 62nd St.

O., Columbus—Dept. of Welfare, Ninth and Oak Sts., awarded contract for a 3,000 kw. turbo generator at State Penitentiary to General Electric Co., 17 South High St., Columbus. $67,000.

Pa., Bradford—City, defeated bond election of November 3 for construction of municipal electric light plant in McKean Co. J. H. Quirk, City Bldg., is city engineer.

Pa., Colona—Pittsburgh & Lake Erie R.R., Pittsburgh and Lake Erie Terminal Building, Pittsburgh, awarded contract for construction of a rail river terminal including mechanical coal handling equipment, to Dravo Contracting Co., Neville Island, Pittsburgh.

Pa., Philadelphia — Philadelphia Steam Co., 49th St. and Grays Ave., subsidiary of Philadelphia Electric Co., 1401 Arch St. and United Gas Improvement Co., 1000 Chestnut St., plans extensions to steam heat supply mains. Estimated cost $4,000,000. Work will be done by day labor or through its subsidiary, United Engineers & Constructors, 112 N. Broad St.

S. D., Rapid City—City Commissioners, will receive bids until November 30 (extended date), for construction of a sewage treatment plant including pumping station, etc. Estimated cost $135,000. Albert Chenoweth, Sioux Falls, is engineer.

Wis., Oconto—City is preparing plans for waterworks improvements including electrification of plant. Estimated cost $61,000. Gordon & Bulot, 53 West Jackson Blvd., Chicago, Ill., are engineers.

Ont., London — Watt & Blackwell, Victor Bldg., Archts., will receive bids until December 1 for a group of buildings including 3 story hospital, 45 x 290 ft. nurses' home, 45 x 60 ft. laboratory building, 50 x 60 ft. addition to boiler plant and installation of 150 hp. boiler for central heating plant for London Health Association, Col. E. I. Leonard, Pres. Estimated cost $300,000.

Ont., Sarnia — Sarnia Curling Club, C. A. White, Pres., 209 North Vidal St., plans construction of a new arena including artificial ice plant. Architect not selected. Ice making equipment will be required.

Sask., La Corne—Sasketchewan Power Commission, Regina, will soon receive bids for construction of a power development on Sacketchewan River, 125,000 hp. capacity near here. Estimated cost $12,207,135. H. G. Acres Ltd., Niagara Falls, Ont., are engineers.

Equipment Wanted

Pump—Fairmount, Ind.—City will receive bids about January 1 for pump, motor, etc., in connection with waterworks system.

Pumps—Versailles, Ky.—City plans to purchase two electrically powered high lift pumps, etc., in connection with waterworks. Estimated cost $50,000.

Electric Motors—Boston, Mass.—H. M. Lobdell, 130 Broad St., plans to purchase one 10, one 15, and one 25 hp., 3600 r.p.m. electric motors, also one 10 hp. 1200 r.p.m. and four 3 hp. 1200 r.p.m. electric motors, each 3 ph., 60 cycle, 220 v. a.c.

Coal Handling Equipment—Palmer, Mass.—Commonwealth of Massachusetts, Dept. of Mental Diseases, State House, Boston, will receive bids until November 27 for coal handling equipment for proposed boiler house at Monson State Hospital, here.

Generating Unit—Iroquois, N. Y.—Division of Standard & Purchase, Capitol, Albany, will receive bids until December 3 for electric generating unit with connections for Thomas Indian School here.

Generator Set—Hampton Roads, Va.—Bureau of Supples & Accounts, Navy Dept., Washington, D. C., will receive bids until December 1, for motor generator set for Navy Yard here. Sched. 6905.

Pumps—Brandon, Manitoba—City, R. McFarlane, Supt., will receive bids until November 27 for supply and installation of two 3 m.g. motor driven pumps, for waterworks, will also consider bids for vertical motor driven turbine pumps.

Regulators—Ottawa, Ont. — Ottawa Hydro-Electric Commission, 75 Laurier Ave. W., will receive bids until November 27 for six 40 kva. automatic induction regulators.

Pumps—Sombra, Ont.—Village of Sombra, plans installation of electric pumps, etc., in connection with waterworks system. $15,000.

Industrial Projects

Ill., Hoopeston—Sprague-Sells Corp., Miller Sells, Mgr., awarded contract for a 1 story factory for the manufacture of food machinery to J. W. Montgomery, 708 Martin St., Danville. Estimated cost $150,000.

Ind., Elkhart—Illinois Carton & Label Co., 2601 North Crawford Ave., Chicago, Ill., will receive bids about December 1 for a 1 story, 130 x 200 ft. factory building at Clark and Elkhart Sts. Estimated cost $40,000. Private plans.

Ind., Howell—Security Oil & Refining Co., plans construction of an oil refinery. Estimated cost $60,000. Work will be done by owners forces.

Ind., Marion—Osborne Paper Co., awarded contract for construction of a 2 story factory building to C. W. Barley, Marion. Estimated cost $40,000. Burt French, Marion, is architect.

Md., Cumberland—Celanese Corp. of America, awarded contract for 1 story, 66 x 170 ft. addition to plant to Wright Richardson & Co., Cumberland. Estimated cost $80,000.

Mass., Cambridge (Boston P. O.)—J. L. Hammett Co., Kendall Sq., manufacturers of school supplies, awarded contract for a 2 story addition to factory to J. M. and C. J. Buckley Co., 183 Essex St., Boston. Estimated cost $40,000.

Mass., Cambridge (Boston P. O.)—Simplex Wire & Cable Co., 66 Sidney St., awarded contract for a 3 story addition to factory at 79 Sidney St. to Chase & Gilbert, Park Sq. Bldg., Boston. Estimated cost $40,000.

Mass., Fall River—American Thread Co., T. R. Louis, Kerr St., plans alterations to power plant. Private plans.

Mass., Lawrence—Beach Soap Co., 125 Lawrence St., awarded contract for a 3 story sulphur building to E. A. Peabody & Son, Bay State Bldg. Estimated cost $40,000.

Mass., Lynn—North Shore Cutting Die Co., J. Hermanson, 898 Broad St., completed plans for a 1 story addition to factory. B. Porter, 209 Washington St., Boston, is architect.

Mich., Detroit—American Blower Corp., 6000 Russell St., acquired a site and plans construction of a 1 story fan factory on Tireman Ave. Architect not selected.